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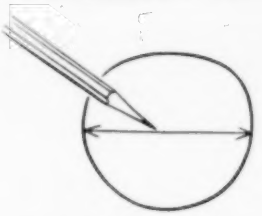

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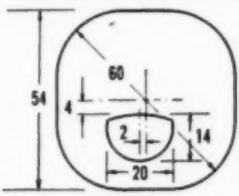

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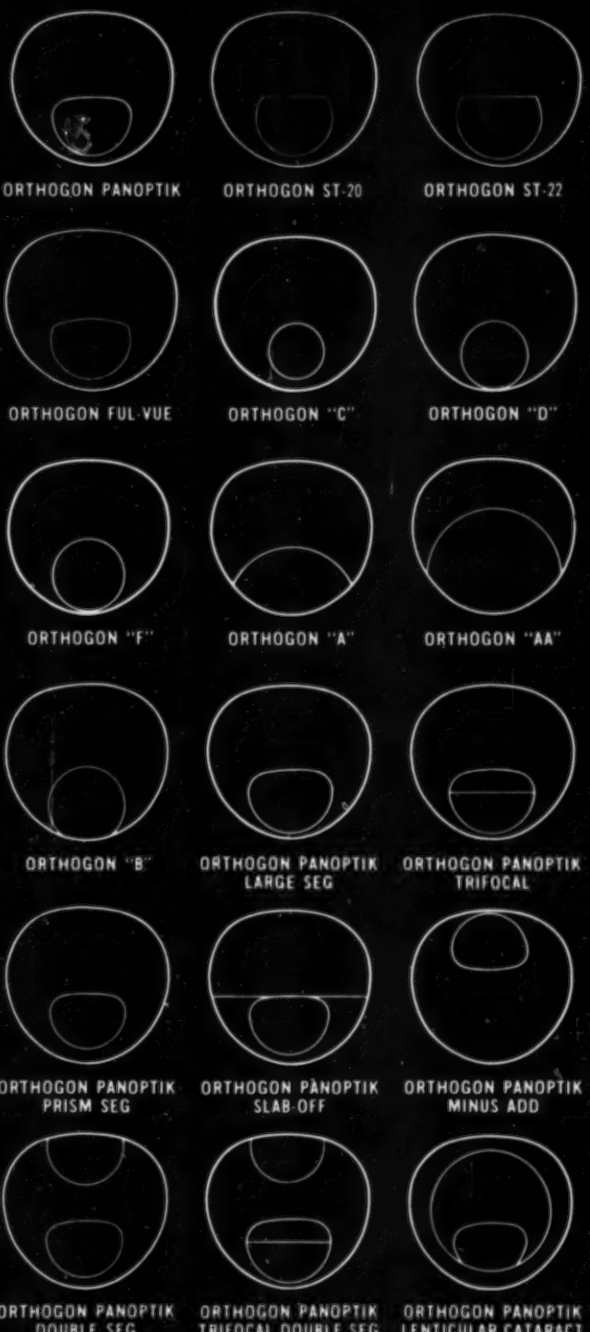

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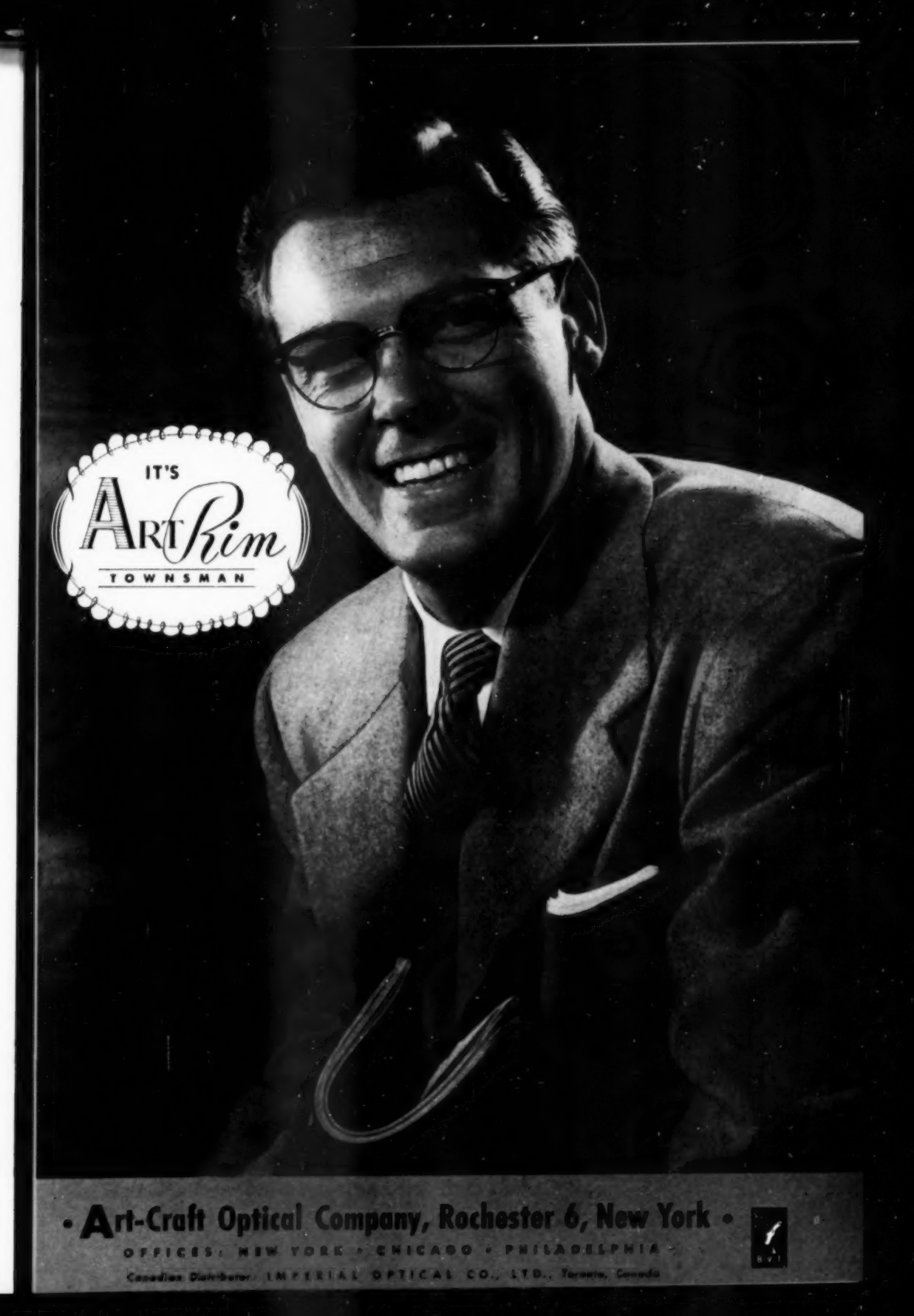
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RESEARCH IN ACCOMMODATION AND CONVERGENCE*

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INTRODUCTION

When a person is told to look at an object which is exposed to both eyes, and he reports that he sees a single clear image, we assume (1) that the eyes are immobile, (2) that the lines of sight (chief rays) connecting the point of fixation and the centers of the entrance pupils correspond in the sense that the images formed by the two eyes fall on corresponding points of the retinas, and (3) that these lines of sight are the primary ones in the sense that the image in each eye falls at the center of the fovea.

As a matter of fact none of these conditions is necessarily fulfilled. The eyes are constantly subject to a slight quiver (physiological nystagmus) and make occasional darts away from and back to the fixation point. The lines of sight from the two eyes that converege at the target do not necessarily correspond (fixation disparity). It may turn out that the image in neither eye falls at the exact center of the fovea. For the present purpose physiological nystagmus is small enough to be ignored. Furthermore, as long as the subject is not known to have an abnormal tendency or capacity for suppression of vision in one eye, and reports that he sees a single image of an object exposed to both eyes, the small amount of fixation disparity present can be ignored. Furthermore, if the target is clear it may be assumed that the image on each retina is at or very close to the center of the fovea.

Therefore, in the normal process of looking at an object, it can be said with the reservations indicated above that the primary lines of sight converge at the point of fixation. The amount of convergence is

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designated by the size of the angle formed by the primary lines of sight at the point of crossing.

It is more convenient to use the centers of rotation than the centers of the entrance pupil to define the angle of convergence because the centers of rotation are fixed with respect to the head. This simplification is possible because as the eye changes its direction of fixation one can find a fixed point in the orbit through which the primary line of sight will always pass, or at least a point from which it will be displaced the least as the eye moves from one fixation point to another. It is located on the line of sight about 13 mm. behind the cornea when the eye is looking straight ahead.

The line connecting the centers of rotation is called the base line. Convergence is said to be symmetrical when the point of convergence lies on a perpendicular bisector of the base line.

There are several writers at the present time who want to use the concept of accommodation to cover a lot of things, including such things as changes in the refracting mechanism of the eye and changes in pupil size. Furthermore, since an observer can affect what he sees by manipulating the impressions after they arrive at the cortex, some writers even want to include cortical processes as a part of the mechanism of accommodation. In the present discussion, however, we want to use it in its most restricted sense. That is to say, we want to think of the mechanism of accommodation as involving only changes in the crystalline lens of the eye induced by contraction of the ciliary muscle.

In some of the experiments about to be described, a method of measuring changes in accommodation has been employed which takes into consideration only changes in the form of a lens and is not affected for example by the size of the pupil. In less controlled situations, such as found in a clinic, it is necessary to use a beam which fills the entire pupil and locate the point of sharpest focus in order to determine changes in accommodation. This sort of measurement is affected by the size of the pupil, the level of retinal illumination and the state of adaptation, but the effects produced by these factors are small and the changes in accommodation which are observed are for the most part produced by changes in the refracting mechanism of the eye.

For the purpose of measuring and specifying changes in accommodations, we define accommodation as a change in the refraction of the eye. The refraction of the eye at a given moment is defined as the reciprocal of the distance from the point for which the eye is accommodated to the spectacle point. Since the eye is not achromatic the point for which it is accommodated will vary with the wave length composition

of the light. The spectacle point is used as the reference point instead of the cornea, principal plane or nodal point because it simplifies the calculation of the effect on accommodation produced by a lens which is placed at this point. Furthermore, the spectacle point which is 14 mm. in front of the cornea lies very close to the focal point and may be assumed to coincide with it, and this facilitates the calculation of the position of the image formed by the refracting mechanism of the eye.

THE NEED FOR RESEARCH ON ACCOMMODATION AND CONVERGENCE

Whenever a person attempts to perform a task, the two eyes converge at a certain point and the separate eyes focus at approximately the same point. During the course of the task he will look first at one point and then at another. The efficiency with which he can perform the task will depend to a large extent upon his ability to converge and accommodate for the various points and to switch quickly from one point to another. The problem is more complicated than it first appears because the two functions are tied together and because two different types of innervation are involved in the maintenance of convergence.

The study of accommodation and convergence is important not only from the point of view of finding out how we may use our eyes more efficiently, but it is necessary in order to understand the cause of eye strain, fatigue and discomfort.

It is also necessary to understand the relationship between accommodation and convergence, because this information is useful in diagnosing lesions in the brain which affect one or the other of these functions.

THE ACCOMMODATION-CONVERGENCE RESEARCH PROGRAM AT THE OHIO STATE UNIVERSITY

The present paper is not intended to be a survey of all research related to accommodation and convergence, but merely a summary of the work undertaken at The Ohio State University since 1935. As a matter of fact, the program was started by Dr. Charles Sheard, in 1914, when the first courses in optometry were taught at The Ohio State University. Sheard and his co-workers contributed a great deal to our understanding of accommodation and convergence, and the work since 1935 has been an outgrowth from the beginning which he made. However, the present paper will attempt to summarize only the work done since 1935. The investigations to be referred to have been carried out by a number of persons, including the writer, his colleagues and students.

ACCOMMODATION AND ACCOMMODATIVE CONVERGENCE

By measuring the lateral phoria with different amounts of accommodation, one can determine the amount of convergence associated with

accommodation. This is called convergence, and the ratio of change in accommodative convergence to accommodation has been called the A.C.A. ratio.

Studies have been made of the variation in this ratio at different age levels, and it has been found that this ratio remains practically constant, decreasing slightly as the age level increases. This constitutes part of the evidence that no more innervation is required to produce a given change in accommodation at one age level than at another, although the amplitude of accommodation decreases with age.

The variation of the A.C.A. ratio from individual to individual at the same age level has been studied and found to be quite variable, ranging from zero to values much in excess of what is needed. The cause of this variation has not been determined.

The same type of relationship between accommodation and accommodative convergence is found to exist in a group of squinters as in a group of normal subjects.

Transplantation experiments in lower animals, in which the internal rectus is attached to the stump of the external rectus and vice versa, are often cited as proving that the relation between accommodation and convergence is learned. These experiments have not been substantiated by experiments in human subjects where efforts to modify the relation by training have not proved successful.

Allen has recently completed a study on the time relationships between the response of accommodation and that of the associated accommodative convergence to a change in the stimulus to accommodation. An ophthalmograph was used to record the changes in convergence and the changes in accommodation were recorded with a movie camera by photographing at a rate of 64 frames per second, an image formed by reflection by the front surface of the lens. This study has shown that accommodation lags behind convergence associated with it by about a tenth of a second. This lag of accommodation behind the associated convergence is probably to be explained in the mechanism of stimulation of the ciliary muscle and the mechanics of imparting the effect of constriction of the muscle to the lens. Further study of these details is needed, but it appears safe at this point to conclude that the impulses sent to the ciliary muscles are synchronous and probably have a common origin in the central nervous system.

FUSIONAL CONVERGENCE

One of the instruments at The Ohio State University for the study of accommodation and convergence belongs to that variety of instruments called haploscopes. It has two arms, one for the right eye and

one for the left eye, on each of which is mounted a target and an optical system for observing it. The stimulus to accommodation is controlled by moving the target toward the eye. The optical system is so designed that this change does not affect the apparent size of the target. Convergence is controlled by rotating the arms around the centers of rotation of the eyes. A special attachment makes it possible to measure the extent to which the eye is over or under accommodated.

While keeping the stimulus to accommodation fixed and equal for the two eyes, one can make the eyes diverge or converge by turning the arms of the haploscope in or out. Through quite a range of convergence the accommodation undergoes only a very slight change, but finally, as convergence increases, a point is reached at which there is a rapid increase in the rate of change in accommodation. These two limits at which accommodation begins to increase and decrease rapidly are defined as the limits of fusional convergence, and it is believed that between these two limits the convergence of the two eyes is maintained by what is called the reflex fusion mechanism. It is believed to be reflex because there is no awareness that the images are being displaced from corresponding points of the two retinas as the stimulus for convergence changes, nor is the subject aware that his eyes are making a compensatory movement to bring the images back to corresponding points.

If convergence is maintained by such a mechanism, this mechanism would have to operate also while the stimulus to convergence is kept fixed except when the stimulus to convergence corresponds to the phoria position. At any other stimulus to accommodation the eyes would be continually drifting back to the phoria position and the fusional mechanism would have to be continually forcing the eyes to bring the images of the fusion stimuli back on corresponding points. A detailed analysis of this problem is being made at the present time by Stewart who is using an ophthalmograph to record fluctuations in convergence with various stimuli to convergence and divergence. About a dozen subjects have been investigated so far. Fluctuations in convergence have been found but do not appear to be a rhythmic drifting away from convergence and a quick movement back to fusion. In order to facilitate this analysis, he has studied the character of fusional movements induced by sudden small changes in the stimulus to convergence. In this connection he has measured the reaction time and the velocity of fusional movements.

One of the problems encountered in research of this type is that of differentiating fusional convergence from accommodative convergence.

One can voluntarily accommodate, and this accommodative response has associated with it the accommodative convergence. Consequently, when a lateral diplopia is suddenly created by a base-in or base-out prism it is conceivable that this might be compensated directly by a fusional movement which is free from any associated change in accommodation or by a voluntary or involuntary effort which brings into play accommodation and accommodative convergence. Momentary blurring suggests that accommodation and accommodative convergence do come into play but are promptly replaced by fusional convergence.

The problem of differentiating accommodative and fusional convergence is even more acute in the situation where the stimulus to convergence has been increased to the point that it is necessary to throw the eye out of focus in order to maintain the eyes converged on the fusion targets. In this situation also the subject is not aware that the eyes are undergoing the compensatory movement to maintain fusion, and up to now we have not been able to formulate a satisfactory concept of the mechanism subserving fusion under these circumstances.

The fact that a different type of mechanism comes in when accommodation starts increasing or decreasing at a rapid rate is proved by the fact that some individuals completely lack the skill to throw accommodation out of focus in order to increase the range. Some individuals may know how to over accommodate to achieve this but not how to relax accommodation, or vice versa. Individuals who lack this skill can be trained to acquire it. In the case of those who have the skill, the amount that the eyes can be made to converge by means of a fusion mechanism before throwing the eye out of focus can usually be increased to a considerable extent with training. The extent to which the eyes can be made to diverge before throwing the eyes out of focus is much less susceptible to training.

Persons with a zero A.C.A. ratio present an opportunity for studying fusional convergence in pure form. The same holds for a person in which accommodation and accommodative convergence are both absent.

VERTICAL FUSIONAL MOVEMENTS

Vertical fusional movements also offer a unique opportunity for studying the character of fusional movements uncontaminated by effects of accommodative convergence.

SIGNIFICANCE OF RELATIVE ACCOMMODATION

By studying the relationship between accommodation and convergence at various levels of accommodation, it has been possible to

prove that any change in accommodation is always associated with a change in accommodative convergence. In other words, it is impossible to make an effort to accommodate without having the accommodative response associated with a convergence response. This statement is quite compatible with the fact that at medium levels of convergence the eyes can undergo changes in accommodation while the overall convergence remains fixed. In this situation the changes in accommodation are associated with changes in accommodative convergence, but the changes in accommodative convergence are compensated by changes in fusional convergence.

This principle is beautifully illustrated at the extreme limit of divergence where the total range of relative accommodation is zero. The inability to accommodate while the eyes are maintained at the extreme limit of divergence is explained by the fact that in order to accommodate it is necessary for this accommodation to be associated with accommodative convergence, but it is impossible for the eyes to compensate this accommodative convergence through the operation of the fusional mechanism because this mechanism is already operating at its maximum capacity at the outset.

RELATION BETWEEN ACCOMMODATION AND CONVERGENCE AT THE MAXIMUM LEVEL OF ACCOMMODATION

A different set of principles operate at the maximum level of accommodation. At the zero level of accommodation there is no mechanical limit to the response of the lens in the sense that the lens will keep on changing form as long as the ciliary muscle can relax. At the upper limit, however, it is believed that the lens reaches a limit beyond which it cannot respond further to constriction of the ciliary muscle. Beyond this limit any effort to accommodate can be made manifest only by an increase in accommodative convergence. The existence of this relationship is clearly shown in certain individuals who can converge a great deal more at the maximum level of accommodation than is indicated by the accommodative convergence and fusional convergence found at lower levels of accommodation. This aspect of the problem is just as important for the theory of accommodation as it is for the relationship between accommodation and convergence. Data obtained with one or both eyes partially paralyzed should be capable of throwing a great deal more light on this problem. The data of this sort now available are somewhat conflicting.

RELATIONSHIP OF PUPIL CONSTRICTION TO ACCOMMODATIVE AND FUSIONAL CONVERGENCE

Knoll has made a study of the relationship between pupil con-

striction, accommodation, and convergence. Although some subjects show a slight change in pupil size associated with fusional convergence, the response associated with accommodation and accommodative convergence is much greater. This again constitutes proof that fusional convergence and accommodative convergence involve different types of mechanisms.

RELATION OF CYCLOPHORIA TO ACCOMMODATIVE AND FUSIONAL CONVERGENCE

Another indirect approach to the relationship between accommodation and convergence is made possible through the study of cyclophoria. When both eyes turn simultaneously to the right or to the left no cyclophoria is induced, but if the two eyes converge, the eyes undergo an increase in excyclophoria. This shows that the pattern of innervation which is responsible for convergence differs from that involved in a change of fixation where one eye turns in while the other is turning out. Allen has made a detailed study of the changes in cyclophoria associated with changes in accommodative convergence as compared to fusional convergence and has found that there is no difference. This may mean that fusional convergence and accommodative convergence make use of the same center or mechanism for convergence in the midbrain.

ERRATA

In the H. W. Hofstetter and David C. Rife manuscript, "Miscellaneous Optometric Data on Twins," Am. J. Optom. & Arch. Am. Acad. Optom. 30.3.139-150, 1953, the illustrations Fig. 9 and Fig. 10 were interchanged. The cut line for Figure 10 should read: Symmetrical heterolateral scatterplots of the corneal astigmatism in the same sample as represented in Fig. 9.

AN ANALYSIS OF FOUR VISUAL SCREENING TESTS AT GRADES FOUR AND SEVEN*

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Children's vision has been considered a part of the program of education in some schools for more than two decades. During this period, there has been a growing interest in the relationship between visual performance and the types of learning which schools expect of children at different levels of maturity. Major attention has been directed to the effects of various visual problems on progress in learning to read. However, the hundreds of published articles, and the dozens of research studies on this subject, reveal that the relationship is still obscure, or even questionable.

Interest in the prevention of blindness, and the development of sight-saving classes has pressed schools into some sort of vision testing. Because of this pressure, many schools have used the Snellen chart as a means of identifying those children who need visual care. However, as early as 1939, Spache[1] questioned the validity of this procedure. The results of his study led him to conclude that the Snellen chart alone should no longer be used as a test of the vision of school children. He pointed to the errors which could be avoided if different tests were employed. During the past 10 years, other research workers have arrived at similar conclusions.

At present, teachers and other school personnel are asking for assistance in selecting the best visual screening test for children. So far, the published research has dealt largely with evaluation of visual screening tests for adults. One of these has been summarized by Imus,[2] who reported on the Ortho-Rater,[3] the Sight-Screener,[4] the Keystone Visual Survey Test,[5] and the Massachusetts Vision Test.[6]

A second attack on the problem of evaluating visual screening tests for adults has been centered in industry. The criterion for identifying the necessary visual skills has been performance on jobs. The tests used have been visual screening tests best adapted for the purpose. It is clear

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that this technique has been very useful, and that vast amounts of data concerning adults have been collected.

It seems logical to assume that the conclusions reached for adult subjects are applicable to children. However, since children's vision is extremely important, research rather than logic is needed to determine whether the results are consistent.

Major Problems: In analyzing visual screening tests for children, attention is directed to five problems. The first concerns the visual functions included in each test battery. It is necessary to determine whether provision is made for testing all of the important visual characteristics, as well as whether unimportant characteristics are included.

The second problem is the accuracy with which each subtest of each visual screening battery measures the visual characteristic which it is designed to measure. Furthermore, it is essential to identify any extraneous factors introduced.

The third problem arises concerning the standards for passing and failing individual test items as well as the entire battery. This problem relates to the validity of the tests.

The fourth problem is to determine the reliability of the test batteries, because only reliable tests are used with confidence as an index of individual performance.

The fifth problem includes consideration of the ease of administration of the test battery, the interpretation of the scores, the cost and availability of the test batteries.

These five problems are discussed in the remainder of this paper. Certain methods for solution are suggested, and wherever possible, data secured from a larger study are introduced.

SCOPE OF THE STUDY

Seven years ago, research was initiated at the University of Chicago Reading Clinic to determine the relationship between visual efficiency and progress in learning to read.* The first step was to identify the visual functions which previous research workers had considered important to reading achievement. Furthermore, refractionists who were working with visual problems of children were asked to suggest additional visual functions for consideration. From these two sources, a list of 16 visual functions were identified.

The second step was to determine whether existing visual screening tests purported to measure these functions, and to secure additional tests as needed. The Keystone Visual Survey Test, the Massachusetts Vision

*This study was made possible by a research grant from Bausch and Lomb Optical Co.

Test, and the Eames Eye Test[7] were examined first because they have been designed for school children. Since the Ortho-Rater and the Sight-Screener were considered among the best tests for adults, an attempt was made to include them in the study also. The Sight-Screener was eliminated because the American Optical Company was not yet ready to have is used with children. The Ortho-Rater, on the other hand, had been adapted for use with children by Bausch and Lomb Optical Company. The changes which were made included an alteration of the lenses so that young children with narrow interpupillary distances could see the targets properly. In addition, the vertical phoria slides were altered to enable children to understand the examiner's directions, and one new experimental slide was added at far distance.

Third, it was necessary to construct and try out several new tests to measure some of the visual functions not included in existing batteries, but considered important by the specialists who were consulted.

The final battery of visual tests included the Eames Eye Test, the Keystone Visual Survey Test, the Massachusetts Vision Test, the adapted Ortho-Rater, and the new tests mentioned above, which are not discussed in this paper. Several standardized tests of reading, and one of intelligence were also used. The tests were administered by the writer, and Dr. Charles B. Huelsman, Jr., who was a research assistant in the Reading Clinic at the University of Chicago. The statistical analysis of these data has been made by the latter.

The subjects were 53 pupils in Grade IV, and 52 pupils in Grade VII of the Laboratory School at the University of Chicago. An entire class was tested to avoid selection. Approximately four and one-half hours of testing time was required per pupil and 82 scores per pupil were finally recorded. The order of administering the tests was varied according to a predetermined pattern so as to eliminate practice effect.

The fourth step was to select a reduced battery of tests[8] on the basis of step three, and administer them to 100 unselected pupils at each of Grades II-VIII. In order to determine the reliability of each test, the entire battery was repeated the same day with 10 of the 100 cases. To determine the validity for referral to a refractionist, another 10 cases at each grade were given thorough visual examination by two refractionists on the same day that the battery of screening tests were administered. Analysis of these data has been limited to an examination of the reliability and validity of the four commercial visual screening test batteries.

From this larger study, data pertinent to an analysis of four visual screening tests have been selected for use in the remainder of this paper. Attention is directed to the fact that the research is still in progress.

Consequently, this discussion can be no more than a preliminary report.

Analysis of Subtests. The first problem, posed earlier, is to identify the visual functions considered by the Keystone, Ortho-Rater, Massachusetts, and Eames tests. Each of the four visual screening test batteries includes a measure of visual acuity at 20 feet, although the targets differ markedly. The Massachusetts test uses an adaptation of the Snellen Test set at 20 feet, with E's for recognition, while the Eames test uses both E's and letters. The testing is monocular with occlusion of the eye which is not being tested, whereas the Keystone and Ortho-Rater do not occlude the opposing eye. The latter employ stereoscopic instruments, presenting targets before each eye as the other is tested. The Keystone calls for recognition of a black dot in a square figure. The Ortho-Rater requires recognition of the position of a black and white checkerboard in a square figure.

Only the Ortho-Rater and Keystone batteries included a measure of visual acuity at near, the distance at which most children read or study. In the past, the assumption has been made that near acuity can be predicted from far acuity with children, hence the Eames and Massachusetts batteries did not include near acuity tests. However, data secured from grades IV and VII in this study do not support this conclusion. The correlations presented in Table I show that agreement varies from .24 to .63.

TABLE I
CORRELATIONS BETWEEN FAR AND NEAR VISUAL ACUITY

Eye	Grade 4		Grade 7	
	Ortho-Rater	Keystone	Ortho-Rater	Keystone
Both	.52	—	.37	—
Right	.29	.63	.49	.24
Left	.34	.40	.43	.39

It is clear that even the highest correlation is too low to predict accurately near visual acuity from scores at far distance. If these findings are substantiated by the study of larger numbers of children, it is apparent that the Massachusetts test omits an important item: namely, near visual acuity. A near-acuity test was added to the Eames battery in 1950 after these data were collected.

Both the Massachusetts and Eames batteries include a test with lenses, to identify children with hyperopia and myopia, while neither the Keystone, nor the Ortho-Rater batteries do. The assumption has usually been made that children who are myopic will score lower than average on the distance acuity tests, and can be identified in this manner on the Keystone and Ortho-Rater batteries. However, no means for identifying

hyperopia is provided in the latter batteries. The importance of hyperopia in children's reading has frequently been emphasized in the literature, but the data secured in this phase of the present study are inadequate to offer an evaluation.

All four batteries include tests for identifying children with vertical phorias at far distance, but only the Ortho-Rater includes vertical phoria at near distance. The correlation between vertical phoria scores at far and near distances on the Ortho-Rater is .33 at Grade IV, and .28 at Grade VII. These co-efficients are sufficiently low to justify very careful analysis of the data by other statistical methods with the larger group of children.

Lateral phoria at far distance has been included in all four batteries. At near distance it appears as a part of each battery with the exception of the Eames test. No attempt is made to evaluate this factor here since the data show that with children, there is general inconsistency among all of the batteries.

Fusion tests at far distance appear as a separate item in the Keystone and Eames tests, but not in the other two batteries. The Ortho-Rater acuity targets provide opportunity for a child to evidence lack of fusion, but the Massachusetts does not consider this factor. In addition, the Keystone provides a near fusion slide. Depth and color tests are a part of the Ortho-Rater and Keystone batteries only.

The important question now is whether all of the functions just discussed are related to children's performance in school, or whether the test batteries including fewer items are sufficient. This question cannot be answered at present, but is the subject for exploration in the more detailed research now in progress.

Accuracy of Measurement. A second problem relates to the validity of each subtest in the visual screening batteries. One means of determining the factors measured by any test is statistical analysis. Where there is a distribution of scores, intercorrelations among the test scores can be calculated. From these intercorrelations, a factor analysis explains the correlations by means of fewer factors than the number of tests in the original measurement. In this way, it is possible to estimate the degree of correspondence between each test and each factor. The names applied to the factors are determined by the research worker. They are based upon hypotheses, which may be tested by adding to the original test battery, tests known to measure particular functions.

This statistical method has been widely used by psychologists to identify primary mental abilities. Furthermore, it was employed by the Medical Research Laboratory of the United States Naval Marine Base,[9]

to identify the factors measured by the acuity, depth, and phoria tests of the Keystone, Ortho-Rater, and Sight-Screener, as well as measures obtained by standard clinical procedures. However, this study was made with adult subjects.

A similar analysis was made with the test results of pupils at Grades IV and VII. However, the scores on the Eames and Massachusetts tests could not be used in this way because they are marked "pass," "questionable," and "fail." The scores obtained on the Ortho-Rater and Keystone were correlated with a number of other tests in the larger study, and factor analyses by the centroid method are calculated.

The visual acuity tests were largely accounted for by four factors at both grade levels. Factor A appeared to have a significant weighting in all tests and is named retinal resolution, as in the adult study just reported. The Ortho-Rater had the highest loading on this factor for the tests at far distance, while the Keystone ranked somewhat lower at both grade levels. Factor B, which appears to be accommodation, shows equal loadings on the two tests. Factor C has not yet been identified since it appears to be somewhat unstable, probably due to the small number of cases in this phase of the research. Factor D appears to be an instrument factor, as tests without instruments have low or negative loadings. The Keystone loadings were slightly higher on factor D than those for the Ortho-Rater.

The acuity tests at near distance contained less of factor A, and more of factor B, called accommodation. This appears to correspond with logical deductions since accommodation is usually required for seeing near targets clearly. The two batteries of tests show almost equal loadings on these factors. However, on factor C, which is not yet named, the loadings were approximately equal but in opposing directions, showing a distinct difference in the targets of the two batteries. Factor D, which appears to be an instrument factor, also showed opposing factor weightings, although they were not of a significant magnitude.

The depth tests were accounted for by three factors at Grade VII, and four at Grade IV, but they are still unnamed. At present, it is only possible to point out that the composition of the depth tests in the Ortho-Rater and Keystone batteries differs markedly. It is necessary to carry the analysis much farther to check hypotheses concerning the nature of the factors before any appraisal is attempted.

The vertical and lateral phoria tests are to be considered in a similar manner, but since much of the statistical data is incomplete, it is impossible to offer a final evaluation at this time. Further use of this

statistical method offers promise of help in identifying what these test batteries really measure.

Standards for Passing and Failing. A third problem is the adequacy of standards for passing and failing each subtest, as well as the entire battery of tests. Standards for passing and failing each section of the Eames, Massachusetts, and Keystone batteries are furnished with the tests, but no standards are available for the Ortho-Rater. However, the latter test was administered several years ago to 599 children in a public grade school by the writer. On the basis of these scores, an arbitrary standard such that 80 per cent of pupils passed each subtest was established. This is only a tentative standard for comparison purposes, and will be redetermined when the more extensive study is completed. However, it is used in the following paragraphs for purposes of comparison.

TABLE 2

AGREEMENT OF THE FOUR VISUAL SCREENING TESTS IN PASSING AND FAILING PUPILS

	Far Acuity Right				Far Acuity Left				Lateral Phoria Far				Lateral Phoria Near				Vertical Phoria Far			
	Ortho-Rater	Keystone	Eames	Massachusetts	Ortho-Rater	Keystone	Eames	Massachusetts	Ortho-Rater	Keystone	Eames	Massachusetts	Ortho-Rater	Keystone	Eames	Massachusetts	Ortho-Rater	Keystone	Eames	Massachusetts
GRADE IV																				
Failed:	15	25	32	15	8	28	30	13	13	32	32	17	15	30	11		8	2		2
Failed this test but passed 2 or 3 others:	2	9	17	2	2	17	17	2	4	19	23	8	9	21	4		6	0		2
Passed this test but failed 2 or 3 others:	4	0	2	2	15	2	0	8	8	6	6	8	4	0	2		0	3		2
GRADE VII																				
Failed:	6	23	25	17	8	21	29	10	13	33	15	17	15	31	19		6	2		2
Failed this test but passed 2 or 3 others:	0	12	13	0	0	10	17	0	2	21	10	6	4	17	2		6	2		2
Passed this test but failed 2 or 3 others:	13	2	2	8	10	0	0	8	6	0	10	6	6	4	0		0	0		0

Note: All figures are percentages.

In order to determine the agreement of the four test batteries, the per cent of pupils failing each common subtest is presented in Table 2, row one. It is evident from the entries that fewer pupils fail the Ortho-Rater and Massachusetts visual acuity tests for each eye at far distance, while a larger percentage fail the Eames and the Keystone. A similar relationship appears for the lateral phoria tests at far distance at Grade IV, while at Grade VII, a lower per cent fail the Eames test.

On the tests of lateral phoria at near distance, the Ortho-Rater and Massachusetts fail a smaller per cent than the Keystone. A larger per cent fail the vertical phoria test at far distance on the Ortho-Rater than on the other two tests.

The consistency with which the pupils pass or fail all four test batteries is shown in rows two and three for Grade IV, and five and six for Grade VII. The first entry in row two shows that 2 per cent failed the Ortho-Rater far acuity test for the right eye but passed two or three of the others, while 17 per cent failed the Eames test for the same eye but passed two or three of the others. All of the other entries in rows two and five may be read in the same way.

The first entry in row three shows that 4 per cent passed the acuity test for the right eye at far distance on the Ortho-Rater but failed on two or three comparable tests in the other batteries. The other entries in rows three and six represent the same type of comparison.

Examination of Table 2 reveals that there is inconsistency in the standards for the subtests of the four batteries. The percentages for the Ortho-Rater and Massachusetts are in closer agreement, consequently they identify fewer pupils for referral to refractionists than the other two batteries. A pertinent question arises as to the adequacy of the standards for passing and failing these subtests of the four batteries. Clearly, the answer is not shown here, because arbitrary standards may be totally inadequate in selecting those children who need visual care.

One method of solving the problem is comparison of the results of the four screening tests with careful refractions. A second method is selection of test items, or patterns of test items which show relationship to school performance.

The validity of each of the four batteries was checked against the findings of two professional refractionists with 79 unselected pupils about equally distributed in Grades I through VIII. The Chi Square[10] statistic was used to determine the degree of association of these results based upon the sample of 79 cases. The results are shown below. The magnitude of the Chi-Squares reveals that the agreement is highest with the Ortho-Rater and Massachusetts, and that the Keystone is also sig-

nificant. However, the Eames test did not select the same pupils as the refractionists.

TABLE 3
AGREEMENT OF SCREENING BATTERIES WITH REFRACTIONISTS

Visual Screening Test	Chi-Squares	Agreement
Ortho-Rater	35.04	Highly significant (1%)
Massachusetts	33.51	Highly significant (1%)
Keystone	12.03	Significant (1%)
Eames	3.06	Insignificant

When reading achievement was chosen as a criterion at Grades IV and VII, no relationship was established with single screening batteries.[11] Only tests of binocular functions not included in these batteries distinguished good from poor readers. Furthermore, group factor analysis revealed a relationship between composite reading scores and near acuity and depth tests. Additional study of these suggested relationships is in progress.

Reliability of the Screening Tests. The fourth problem concerns the consistency of each battery based upon repeated testing of the same subjects. The manual for the Eames test[12] reports that the entire battery agreed with itself in 93 per cent of the 100 school children tested. The manuals for the Keystone and Massachusetts provide no comparable data on reliability, and no data are available for these three batteries based on the current research.

However, the Ortho-Rater battery was administered twice to 69 children in Grades II through VIII. The reliability coefficients for the far acuity tests were .81 and .68 for right and left eye respectively, while at near they were .82 and .77. The coefficients for lateral phoria at far was .80 and at near .62. A coefficient of .80 was obtained for the depth test. The vertical phoria tests did not lend themselves to this statistic because too many pupils obtained a single score. It is interesting to note that in general the means for the acuity and depth tests were higher and the standard deviations lower on the second test. Such a change reveals that practice improves the scores.

The results of the two administrations of the entire Ortho-Rater battery shows 77 per cent agreement, with a Chi-Square showing agreement well beyond the 1 per cent level of confidence.

Other Considerations. The fifth problem includes several practical considerations of the visual screening tests. For school use, it is important that these tests be given by persons who are not trained refractionists. The four batteries considered here require no technical background for use, and a teacher who recognizes the significance of

following directions carefully can administer them. The writer has no objective data concerning the ease with which their use can be learned. However, graduate students in an advanced course in clinical reading have expressed decided preference for the Ortho-Rater. Some reasons offered for their preference are: (1) only a small space is required rather than 20 feet; (2) proper light is provided in the instrument; (3) adjustments must be made only for the height of the child; (4) targets can be changed by merely rotating a crank; and (5) the directions for administration are clear and simple.

The Eames, Massachusetts, and Keystone batteries are accompanied by directions for administration. Responses to each subtest are clearly marked "pass," "questionable," or "fail." Instructions are provided as to which scores constitute the need for referral for a professional visual examination. This information is not yet available for the Ortho-Rater, because research is in progress with the hope of establishing an interpretation of scores which will be valid for the refractionist, as well as meaningful for school performance.

The cost of visual screening tests is important to schools also. The Eames Eye Test is quite inexpensive, the Massachusetts costs considerably more, and the Keystone is most expensive. The cost of the School Ortho-Rater is not yet known. It is clear that evaluation of expenditure for a visual screening battery should be secondary to such factors as validity, reliability, and usability.

Summary. The foregoing discussion has served to identify five major aspects of an evaluation of visual screening tests for school children. The objective data presented are preliminary, and based in part on research in progress. The purpose of that study is to determine the relationship between visual characteristics and reading progress. The major part of the data has been limited to Grades IV and VII.

The analysis has pointed up specific problems which arise in attempting to assist school personnel in selecting visual screening tests. The first problem concerns the visual functions included in each of the batteries. Visual acuity and lateral phoria tests at 20 feet, or far distance are a part of each of the batteries; vertical phoria at far distance and lateral phoria at near distance are included in three batteries; acuity at near, depth, and color are considered by only two batteries; and fusion targets appear in a single screening test. It is essential to determine the importance of these visual functions before final appraisal is made of the adequacy of each battery.

A second problem is the accuracy with which each subtest measures the characteristic it is designed to appraise, without introducing ex-

traneous factors. Since the techniques of testing employed by the four batteries vary widely, this type of evaluation is important. Preliminary data presented in this paper reveal that the composition of the traits measured by the subtests of the Keystone and Ortho-Rater differ in many respects. Further analysis of these factors with larger groups of children offers promise of a solution.

A third problem deals with the standards for passing and failing individual test items, and the entire test. The data presented here show considerable variation in the per cent of children at Grades IV and VII who pass and fail the four batteries. Comparison of the pupils identified by these batteries and those identified by two refractionists reveals that the Ortho-Rater, Massachusetts, and Keystone batteries are most accurate. At present, it is not possible to relate these tests to school achievement.

The reliabilities of the subtests and the entire batteries need further exploration with children. Data on the Ortho-Rater only are provided by this study.

Additional considerations for school use include the ease of administration and interpretation, and the cost of the test batteries.

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A POSSIBLE WAY TO EXTEND THE USE OF THE PERIMETER*

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During my senior year at The Ohio State University I was introduced to an instrument called a haploscopic tangent screen constructed by Dr. Glenn Fry. (Figure 1.) This instrument was simply a tangent

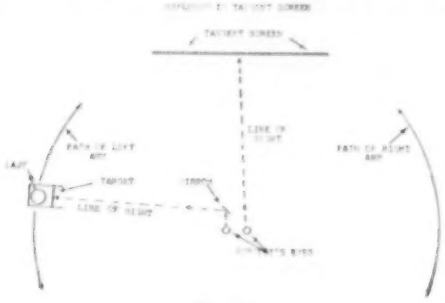

Fig. 1

screen about two feet square which could be rotated around the center of rotation of the eye being plotted while the opposite eye fixated a target viewed through a mirror. The mirror and target were mounted on an arm so arranged that it could be roated around an axis with its center the same as the center of rotation of the fixating eye. This made it possible to compensate for any lateral deviation of the eyes so that one eye could be fixating while the central visual field of the opposite was being plotted. At that time we were interested in plotting the suppression areas of strabismics, and it was a good arrangement for setting up the objective angle of squint and having the individual fixate with his guiding eye while the suppression area of the squinting eye was plotted. The tangent screen covered an area of 60° laterally and vertically and was divided into 5° squares. At its center was a hole large enough to expose a light used to obtain a corneal reflex. By sighting through this hole one could view the eye to be plotted and move the tangent screen or the fixation target around the arc in front of the other eye and in

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this way align the instrument so the test could be made. After the setting a plug was inserted into the hole to complete the screen. Either eye could be used as the fixating eye as there were two arms which held the mirrors and the targets and each was removable so that either could be used.

An example of a suppression area measured on this instrument is shown on Figure 2. This is the case of a 19-year-old squinter whose

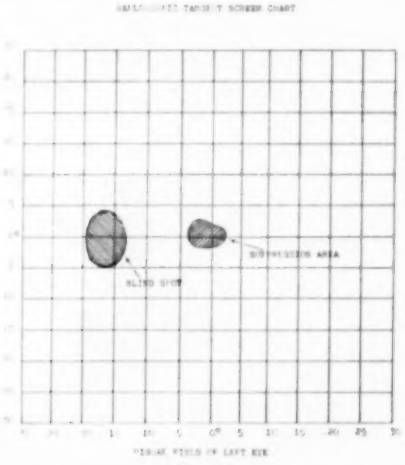

Fig. 2

subjective and objective angles of squint measured 10° esotropia on a synoptophore which was fitted with a special sighting arrangement for viewing the corneal reflex when measuring the objective angle of squint. The patient was a concomitant monolateral squinter using his right eye as his fixating eye. Also he was ambloyopic in his left eye to the extent of 20/200 visual acuity. His correction was: O.D. +2.50 D. sph. O.S. +2.50 D. sph. ⊂ —1.25 D. cyl. axis 180 and the angle of squint was taken through this correction as well as the measurement of his visual field. As can be seen from the figure the suppression area is approximately 6° across and 4° vertically. One characteristic of this scotoma was that it came and went and if too much time were taken in measuring it, it disappeared altogether. Also shown plotted on the diagram is the blind spot for that eye. This serves as a good control and gives us first hand information as to where the foveal area is or at least where it should be.

It has been my experience that this is an example of a very small

suppression area. I have found that this area is usually from 10° to 15° in diameter and may even be complete as far as small test objects are concerned. I have also found that as soon as an individual becomes conscious of what he is doing he usually learns to use this area, consequently care should be taken to remind the subject to keep fixating with his guiding eye. Even then if too much time is taken the suppression area may disappear for a time. One may even have to wait a few days to attempt to measure it again.

This is the basis for the procedure adopted and made possible by adding the necessary accessories to a perimeter for what was thought would be approximately the same use. The instrument used was the Brombach perimeter manufactured by the American Optical Company and is shown in Figures 3, 4, and 5. This instrument has two chin

Fig. 3

rests and the chin can be placed in one or the other depending on which eye is being measured. The tangent screen of the perimeter is fixed so that it can be rotated around the arc in front of the eye being measured. The target, which is to be fixated by the opposite eye, is mounted on an arm so that it can be sighted through a mirror 45° to the line of sight of that eye. The center of rotation of this arm is approximately the same as the center of rotation of the fixating eye and can be rotated to help compensate for any lateral heterotropia or phoria. Vertical imbalance may be corrected with a prism in front of the fixating eye.

Two mirrors were devised so that either could be used depending on which eye was to be used as the fixating eye. With this arrangement

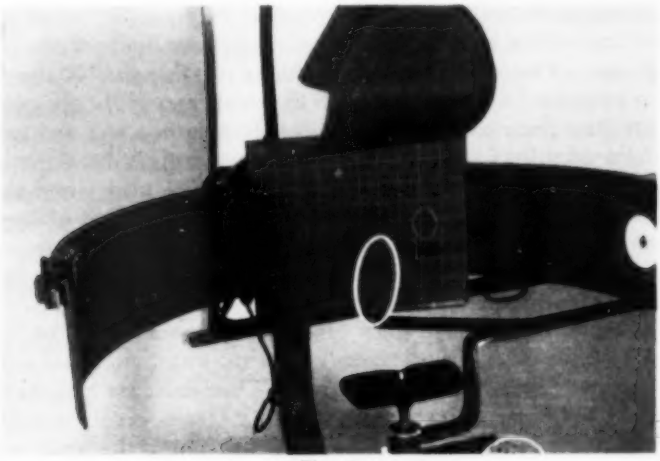

Fig. 4

we can measure, within limits, a heterotropia and phoria as well as map out the central visual field of the eye not doing the fixating.

In the author's practice this instrument is used primarily for the analysis and treatment of squint cases, but we are using it for other types of cases, as will be discussed and shown later.

The subjective angle of squint can be measured by having the patient fixate the target on the arm, and point to the place on the screen

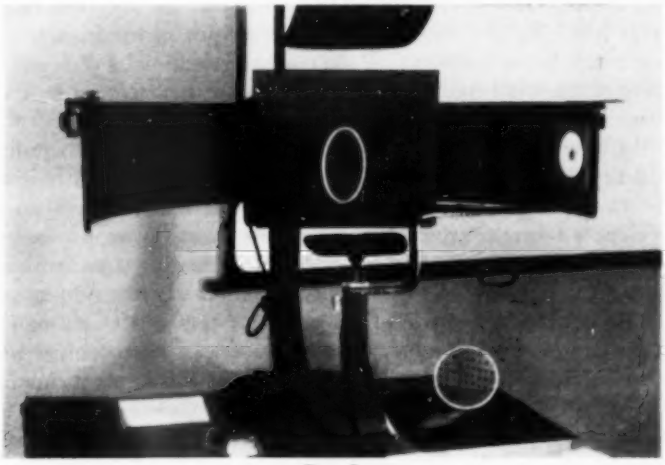

Fig. 5

that coincides with the center of the target. The tangent screen can be moved around the arc if it fails to fall within the limits of the central visual area. This gives us a rough idea as to what part of the visual field is being used to correspond with the foveal area of the opposite eye. We can then put a cross at the center of the tangent screen and move it around until it lines or coincides up with the target. A direct reading of the lateral subjective angle of squint can then be made from the arc of the perimeter. It is usually best to mark this point with a white crayon and line it up several times with the target of the squinting eye as a check on the original findings. A vertical imbalance may be read from the tangent screen graph by essentially the same method.

The lateral objective angle of squint can be measured by having the subject fixate with his fixating eye on the target and place a bright light at the center of the tangent screen. Then move the tangent screen with the light at its center until the reflex centers on the cornea just slightly to the nasal side of the center of the pupil of the squinting eye. This can be checked, if the subject has foveal fixation in each eye, by having the individual fixate from the target to the light several times. If there is a jump in the reflex, the light can be moved to correct for it. A direct reading from the instrument as before mentioned will give the objective angle of squint. This will give a measurement of the vertical as well as the lateral imbalance. If there is no foveal fixation possible in one eye or the other the approximate lateral objective angle of squint can be determined by the first mentioned method. In this event, however, a vertical imbalance could not be measured because the view that the observer has from the top of the screen does not permit a view of the corneal reflex at the same level as the center of rotation of the eyes. The plotting of the blind spot if it is possible, however, would, in most cases, give this information.

By leaving the instrument set at the objective angle of squint one should first attempt to plot the blind spot as a control. After finding the blind spot, and it is usually somewhere near where it is supposed to be, we know where the fovea is and can plot the suppression area if there is one. This also seems a fairly sure way of knowing if we are dealing with the real and not the functionally anomolous corresponding points of the two retinae. The size of the perimeter test object used will vary with the degree of amblyopia and suppression. Of course this technique is not fixed and often has to be varied to meet the requirements of the case involved.

An example of the use of this instrument for the measurement of a suppression area is as follows. This is the case of a boy, age 10, who

had no traceable hereditary background as the cause of his squint and who has had no previous glasses, operation, or treatments to correct his difficulty. His parents reported that he had had encephalitis at the age of 3 and that they noticed his right eye deviating slightly afterwards. His pupillary reactions were normal both direct and consensual and there was no evidence of paralysis of any of the extra-ocular muscles. He was a monolateral, concomitant, exotrope of about 10° with 5° of left hypertropia with the subjective and objective angles of squint measuring the same.

His left eye is his fixating eye. Figure 6 is the graph of the central

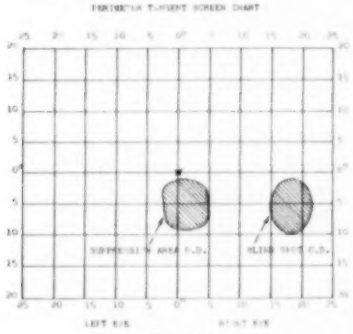

Fig. 6

visual area and shows the suppression area directly over the foveal area. This was taken with the left eye fixating and the instrument set at the angle of squint. This suppression was total for the entire visual area as far as 1° and 2° test objects were concerned. A 3° test object had to be used for this individual in order for him to perceive any movement in the field of his right eye. Yet with his left eye occluded the field of the right eye was normal and the visual acuity 20/20. The patient had no optical error. His main symptoms were frontal headaches.

In the case of squint, after the blind area is plotted, we have definite information as to where the fovea should be and can make use of this information also as a beginning orthoptic procedure. Different means may be used to stimulate this foveal area to break up suppression and attempt to give at least a rudimentary form binocular vision. This has been a real help to us in treating our strabismics.

The same procedure can be used for plotting the visual field of amblyopes and scotomatous areas of eyes in which the foveal area is no longer useable, as is used in measuring suppression areas.

Figure 7 is the visual field of a 15-year-old amblyope. Her present

correction is O.D. +3.00 D. sph. ⊂ —1.00 D. cyl. axis 45. O.S. +4.50 D. sph. ⊂ —1.50 D. cyl. axis 155 and the visual acuity is

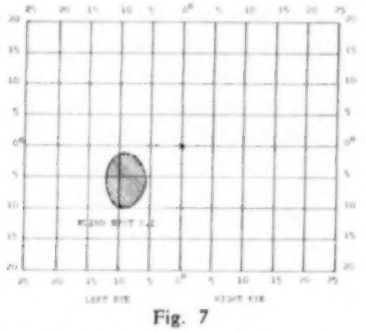

Fig. 7

O.D. 20/25 and O.S. 20/200. During the examination she was found to have 40° esophoria with low negative fusional reserve but still able to fuse at 2° base-in. There was no vertical imbalance measurable. This finding was taken with the rotary prism on the phoropter. The perimeter was set at the objective angle of imbalance and the blind spot was plotted with the right eye fixating the target.

The blind spot was then plotted with the left eye fixating the cross at the center of the tangent screen with and the right eye covered. Both ways of measuring the visual field showed the blind spot to be in the same position. These findings indicated that the patient not only was using an extra foveal point for fixation but also had an anomalous angle between the pupillary axis and the blind spot. It also indicated that she had anomalous correspondence. Her true imbalance as indicated from the graph would be about 5 degrees of vertical and 5 degrees of

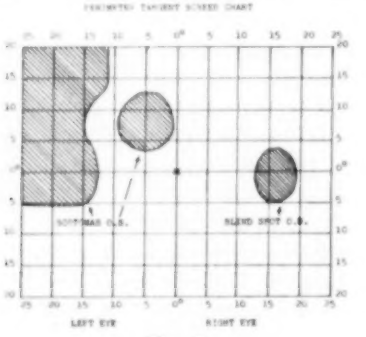

Fig. 8

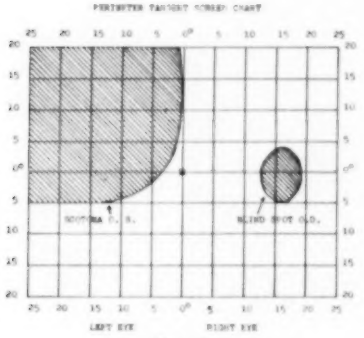

Fig. 9

lateral. Prism could not be incorporated in her prescription, however, as it gave her diplopia.

The next case is one which shows the use of the instrument on a patient whose central fixation was almost destroyed. At the start the visual field was plotted in the customary manner but later it was mapped by using the attachment for the perimeter because of the difficulty in fixating with the left eye. Figures 8, 9, 10 and 11 show what happened to the visual field during the development of a tumor of the pituitary gland, from a partial to an almost complete bilateral hemianopsia. Each figure represents the central visual area of the right and left eye taken on the same date. These tests were made with a ½° test object. This case was diagnosed, referred, and followed through treatment and operation by the writer and the results recorded. The visual field in Figure 8 was taken June 10, 1951; Figure 9, July 10, 1951; Figure 10, Sept. 18, 1951; Figure 11, January 21, 1952; and Figure 12, June 10, 1952. Radium treatments were given to her between Septem-

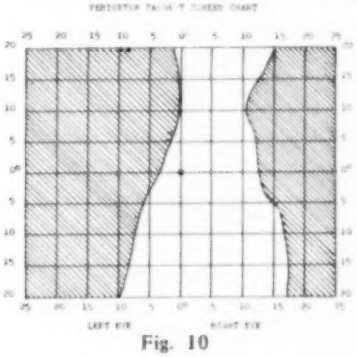

Fig. 10

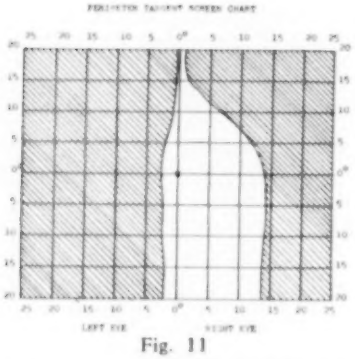

Fig. 11

ber 18, 1951 and January 21, 1952, and while they seemed to halt the progress of the tumor for a time, it started growing again, as can be seen from Figure 11.

The patient was operated on about April 20, 1952. The results of the operation were very good and the patient recovered some of her lateral vision as shown in Figure 12, which was taken June 10, 1952. As could be seen from the figures, the left field was affected more then the right one. Consequently in this case, as shown in Figures 10 and 11, the right eye did the fixating while the left one was being plotted because of the difficulty in fixating with the left eye. This patient's correction is as follows: O.D. +2.75 D. sph. ⊂ —0.50 D. cyl. axis 90. O.S. +2.75 D. sph. ⊂ —0.50 D. cyl. axis 45. This changed only slightly during the growth and removal of the tumor. As might be expected, her vision diminished from 20/25 O.U. to O.D. 20/40 and O.S. 20/60. Her phoria gradually changed from 1° exophoria at the beginning to 6° esophoria at the time of her operation. Her negative

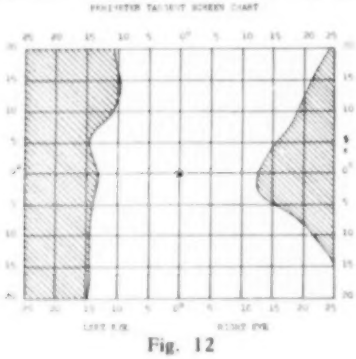

Fig. 12

fusional reserve also changed from x/12/4 to x/8/0. Her chief symptoms were headaches, loss of vision on the left side, and inability to read as comfortably as before.

Figure 13 illustrates the visual field of a patient 58 years old who

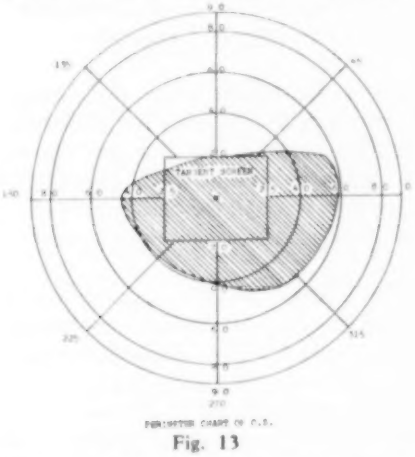

Fig. 13

has no central fixation with his left eye. Consequently the instrument was set with the right eye fixating the target while his left eye was measured. In this case the tangent screen was not large enough to cover the extent of the scotoma, so the measurements about and below the limits of the tangent screen were estimated. A 3 degree test object had to be used because of the low acuity of the periphery of the retina and even then the object was very indistinct at times. The correction the patient was wearing is O.D. +1.37 D. sph. ⌢ —0.75 D. cyl. axis 180. O.S. +3.00 D. sph., with a +2.00 D. sph. addition O. U. No fusional findings were possible and no deviation of the eyes seemed to be manifest. The patient has had this difficulty since he was 18 years old but does not seem to know the cause. He has no symptoms.

CONCLUSION

The writer would like to state that he has described a device and procedure which he has found helpful in analyzing and treating squint cases and mapping the visual fields of patients who have little or no means of fixating with one eye or the other.

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THE MEASUREMENT OF OBLIQUE ASTIGMATISM IN OPHTHALMIC LENSES*

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In the design of ophthalmic lenses the designer must establish several conditions which should be met when the lenses are finally fitted. Two of these conditions are (a) the distance between the back vertex of the lens and the center of rotation of the eye, and (b) that the optic axis of the lens must pass through the center of rotation of the eye. The former is a parameter, the latter a prerequisite to simplification of the calculations.

The back vertex to center of rotation distance chosen by the various manufacturers ranges between 25 and 27 millimeters. The measurements made by Bannon and Walsh[1] showed that among one thousand patients the mean eye-wire distance was 11.2 millimeters, with a standard deviation of 1.75 millimeters. Hence, in the range plus and minus two standard deviations, the eye-wire distance would lie roughly between 9 and 13 millimeters anterior to the cornea. If one assumes that the center of rotation lies 13 millimeters behind the cornea the eye-wire to center of rotation distances fall in a range from 22 to 26 millimeters. If one now assumes a 3 millimeter back vertex depth for the run of the mill correction, the back vertex to center of rotation distance might be expected to lie between 25 and 29 millimeters. The designers have, in other words, chosen values for the back vertex to center of rotation distance which would fall into the fitting specifications of the population as sampled by Bannon and Walsh.

What error is introduced if the lens is not fitted at the exact distance for which the base curves were computed? This may be answered partly by noting the change in base curve per millimeter change in the back vertex to center of rotation distance. The optimum base curves for 20 and 28 millimeters distances are shown in Figure 1.[2] It will be noted that the optimum base curves become deeper as the lens approaches the center of rotation. The change in base curve amounts to roughly 0.4 diopter per millimeter change in back vertex to center of rotation dis-

*Read before the annual meeting of the American Academy of Optometry, Rochester, New York, December 8, 1952. For publication in the April, 1953, issue of the AMERICAN JOURNAL OF OPTOMETRY AND ARCHIVES OF AMERICAN ACADEMY OF OPTOMETRY.

†Ph.D. Dean of College. Fellow, American Academy of Optometry.

[1]Bannon, R. E., and Walsh, R., on Astigmatism, Part II, Am. J. Optom. & Arch. Am. Acad. Optom., 22, 172, 1945.

[2]von Rohr, M., and Boegehold, H., Das Brillenglas als Optisches Instrument, Julius Springer, Berlin, 1934.

tance. This approximate figure was computed for vertex powers falling in the range plus 4 diopters to minus 4 diopters.

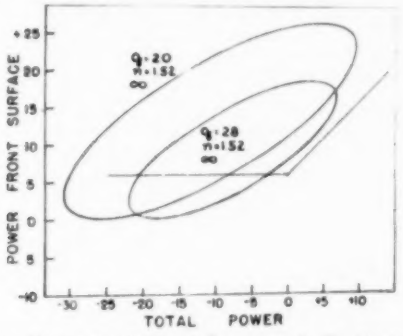

Fig. 1. Optimum Base Curves for Spectacle Lenses. q is the distance between the back vertex of the lens and the center of rotation of the eye. Drawn for objects at infinity. The straight lines represent the base curves in six base lenses. (After von Rohr.)

This study was undertaken to find a more complete answer to the above question. The oblique astigmatism at 30 degrees from the axis was measured for various spherical lenses ranging in vertex power from plus 6.50 diopters to minus 7.50 diopters. For each vertex power chosen, three base curves were chosen: one base curve was chosen as the optimum for a back vertex to center of rotation distance of 25 millimeters. The other base curves were chosen two diopters either side of this optimum value. All lenses were measured at vertex distances of 20, 25 and 30 millimeters.

The measurements were made on a modified American Optical Lensometer. The modification consisted of a jig fitted to the lens ring of the Lensometer which would locate 50 millimeter round lenses at the desired distances and angles, and a tiny point of light target in place of the line target usually found in this instrument.

The data are summarized in Table I. t represents the center thickness of the lenses, Fv the vertex power, F_1 the outside base curve, and q the back vertex to center of rotation distance. Single readings represent an astigmatic interval which was too small to be detected with the present technique. Double readings represent the readings for the two astigmatic lines. It will be noted that the two variables, namely, base curve, and back vertex to center of rotation distance, introduce errors of roughly the same magnitude. In only a few instances does the reading for either astigmatic line vary more than one-quarter of a diopter from the vertex power of the lens. An error of this magnitude at 30 degrees from the optic axis is not considered serious by this author. It would

TABLE I

t (mm)	Fv	F1	Readings at 30° from optic axis q=20 mm.	q=25 mm.	q=30 mm.	Angle of tilt producing one eighth diopter cylinder—one quarter diopter cylinder
5.2	+6.50	+14.00	6.25	6.00	6.12	
5.1	+6.50	+12.00	6.50	6.25	6.25	
5.3	+6.50	+10.00	6.37	6.25	6.25	8°—11°
			6.87	6.75	6.62	
4.5	+4.50	+12.00	4.25	4.12	4.25	
4.2	+4.50	+10.00	4.37	4.25	4.12	
4.1	+4.50	+ 8.00	4.50	4.37	4.37	9°—14°
			4.75	4.62	4.62	
3.2	+2.37	+10.00	2.25	2.25	2.12	
2.9	+2.37	+ 8.00	2.37	2.37	2.25	
3.0	+2.37	+ 6.00	2.37	2.37	2.37	13°—18°
			2.50			
1.8	—1.62	+ 8.00	.....	—1.50	—1.37	
1.8	—1.62	+ 6.00	—1.50	—1.62	—1.50	
			—1.87			16°—22°
1.7	—1.62	+ 4.00	—1.62	—1.62	—1.50	
			—1.87	—1.87	—1.87	
1.0	—3.62	+ 6.00	—3.50	—3.50	—3.25	
			—3.75			
0.9	—3.75	+ 4.00	—3.62	—3.50	—3.50	
			—3.87	—3.75		10°—15°
1.0	—3.62	+ 2.00	—3.75	—3.62	—3.62	
			—4.12	—4.12	—4.00	
1.0	—5.50	+ 5.00	.....	—5.25	—5.00	
					—5.25	
0.9	—5.62	+ 3.00	—5.50	—5.37	—5.37	
			—6.00	—5.62		8°—12°
1.0	—5.62	+ 1.00	—5.75	—5.75	—5.62	
			—6.50	—6.37	—6.00	
1.0	—7.50	+ 4.00	.....	.....	—7.25	
1.0	—7.62	+ 2.00	—7.50	—7.37	—7.50	
			—8.00	—7.75		7°—10°
1.0	—7.62	0.00	—7.87	—7.75	—7.75	
			—8.75	—8.50	—8.37	

seem that variations in base curve and back vertex to center of rotation distance in the range measured here do not seriously mar the performance of ophthalmic lenses.

At the outset it was assumed that the optic axis of the lenses would pass through the center of rotation of the eye. It is doubted that this is the case in actual fitting of spectacles. The introduction of pantoscopic tilt is likely to introduce an astigmatic error of an objectional magnitude—even at the center of the lenses. To check this possibility the angles of tilt, as defined by Fry and Ellerbrock,[3] were computed which would produce respectively one-eighth and one-quarter diopter of cylinder at the center of the lenses. These values are given in the last column of Table I. The computed values were checked with the

[3]Fry, G. A., and Ellerbrock, V. J., Placement of Optical Centers in Single Vision Lenses. Optometric Weekly, September 25, 1941.

modified Lensometer and were found to agree within the error of measurement. It may be noted that as much as one-quarter of a diopter of cylinder can be introduced in all of the lenses having a vertex power greater than 3 D. by an angle of tilt equal to 15 degrees. Many spectacles are fitted with angles of tilt of this order of magnitude. The astigmatic error thus introduced could be avoided by proper decentration, but this procedure is rarely if ever carried out.

The values presented above correspond to those encountered when the eye is in the primary position. the aberration may be expected to increase as the line of sight deviate from the primary position. It is planned to extend the measurements to include other positions of the line of sight.

SUMMARY AND CONCLUSIONS

The oblique astigmatism has been measured for several lenses at 30 degrees from their optical axes. For each vertex power used, three base curves and three back vertex to center of rotation distances were used. Angles of tilt which would produce one-eighth and one-quarter diopter of cylinder were computed and measured for each of the vertex powers used.

The following conclusions may be drawn from the foregoing:

(1) Variation in base curves two diopters on each side of the optimum does not introduce objectionable errors of astigmatism up to 30 degrees from the axis in the lenses measured.

(2) The distance between the back vertex of the lens, and the center of rotation of the eye in each of the above lenses may be varied between 20 and 30 milimeters without introducing errors greater than those introduced by the above mentioned base curve changes.

(3) Tilting the lenses 15 degrees introduces astigmatic errors between one-eighth and one-quarter diopters at the centers of the lenses.

(4) This astigmatism, which may arise as the result of improper fitting, may exceed the astigmatism encountered in oblique gaze, thus negating the efforts of the lens designer.

(5) Astigmatism which would be encountered in oblique gaze with tilted lenses has not been measured. These measurements are forthcoming.

(6) It is recommended that the fitting procedure outlined by Fry and Ellerbrock[3] be followed in order to avoid astigmatic errors due to tilting of lenses.

(7) Measurements of oblique astigmatism for objects at finite distances have not been studied thus far. These measurements are being planned.

AN INVESTIGATION OF THE FACTORS AFFECTING THE FIELD OF FIXATION THROUGH MULTIFOCAL LENSES*

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INTRODUCTION

The field of fixation can be defined as that part of the object space within which any point is focused on the fovea by an ocular movement while the head is held stationary. This definition differs from the definition ordinarily used for the field of fixation in that a clear focus of the object point is required.

If an eye does not require a spectacle lens to produce clear vision, the field of fixation is determined principally by the anatomical arrangements of the eye, the orbit, and the adnexa of the eye and orbit. In the different principal meridians, average values for the fields of fixation are 60 degrees up, 75 degrees down, 60 degrees in and 100 degrees out.[2]

When a refractive correction is worn before the eye for distance vision, the field of fixation as defined for this study partially is determined by the size and shape of the correcting lens. In addition, the field of fixation will be affected by the viewing distance, the power of the lens, the vertex distance, and the size of the pupil.

The field of fixation differs from the field of view in that the eye is considered to be mobile and that the reference point is the center of rotation of the eye.[1, 3] For the field of view, the eye is assumed to be stationary and the center of the entrance pupil usually is used as the reference point.[9]

With multifocal lenses, one or more segments are added to the lens supplying the distance correction. These segments vary in size and shape but in all cases represent an area in the distance lens of markedly different refractive power. This difference is commonly known as the "add"; it is constant for the entire area of the segment.

In addition to the various factors affecting the field of fixation through the distance correction, the field of fixation through the segment

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further is affected by the "add" as well as the size and shape of the segments. The present investigation was undertaken to investigate the interrelationship of all the factors affecting the field of fixation through segments of multifocal lenses.

MATHEMATICAL FORMULATION

The field of fixation usually is specified as an angle. For the mathematical formulation of this problem, however, it is more convenient to use the tangent of the angle. As example, consider Figure 1. Here, the

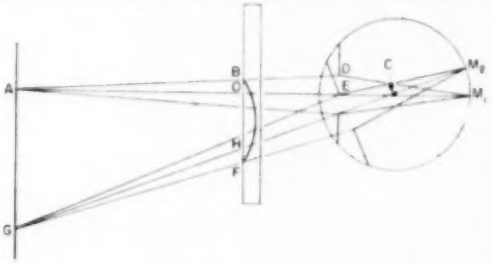

Fig. 1

angle ACG is defined as an angular field of fixation. The tangent of the angle is the distance AG; it is this measure that principally will be employed in this study.

In Figure 1, the line AG represents a plane perpendicular to the median sagittal plane of the head and the straight forward position of the line of sight. The distance AO is the viewing distance; OC is the vertex distance plus a constant of 12 millimeters. This constant is the distance from the anterior surface of the cornea to the center of rotation of the eye.[3] The letters A and G stand for two points of fixation. From the figure, it is seen that all the rays from points A and G that enter into the eye pass through the segment BF. For points slightly above A or below G, at least a part of the rays are intercepted by the distance portion. This condition would result in a doubling of the point fixated and may not be tolerated by a wearer of such a lens. Consequently, in order to define the width of the maximum field of fixation that can be observed through the segment without encountering this difficulty, the distance OH will be called the useful portion of the segment through which no doubling of the image occurs.

The field of fixation obtained when the chief rays from points A and G pass through B and F respectively, is defined as the field of fixa-

tion with doubling. The interception of the bundles of rays by the segment for the two fields of fixation is illustrated in Figure 2.

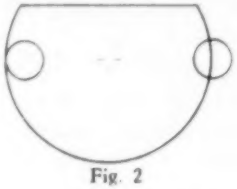

Fig. 2

By inspection of Figure 1, it follows that

$$AG = \frac{(AC)\ (OH)}{(OC)} \tag{1}$$

Also

$$OB = \frac{(AO)\ (ED)}{(AE)} \tag{2}$$

where ED is one-half the diameter of the pupil. Since

$$OB = HF$$

it is apparent that

$$OH = BF - 2\left\{\frac{(AO)\ (ED)}{(AE)}\right\} \tag{3}$$

The distance OH cannot be determined readily while BF can be measured directly from the lens. Consequently, it is desirable to express OH in terms of BF. From (1) and (3) it follows that

$$AG = \frac{AC}{OC}\left\{BF - \frac{2\ (AO)\ (ED)}{AE}\right\} \tag{4}$$

All of the above distances are either so fixed that they may be considered as constants or easily are determined.

In Equation 4, no consideration was given to the power of the correcting lens upon the field of fixation. That it does have a marked effect is apparent from Figure 3. From the figure, it is seen that the

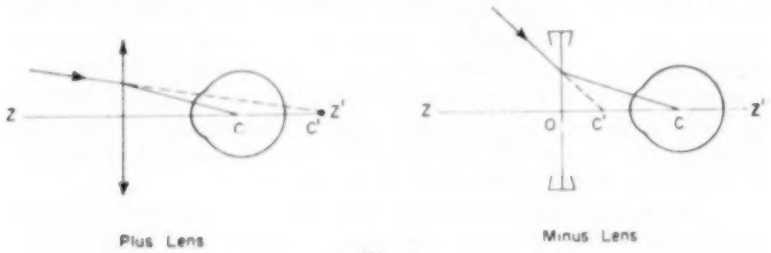

Fig. 3

power of the correcting lens for the hyperope reduces the field of fixation: just the opposite occurs for the myope. For both cases, rays of light have to be directed toward the image of the center of rotation C', if after refraction by the correcting lens they are to pass through the actual center of rotation C. This produces the effect of altering the reference point within the eye in the measure of the angular field of fixation.

In Equation 4, the actual center of rotation of the eye was employed as the reference point; without significant error the equation can be altered for the image of the center of rotation, as follows:

$$AG = \frac{AC}{OC'} \left\{ BF - \frac{2\ (AO)\ (ED)}{AE} \right\} \qquad (5)$$

Since OC' cannot be readily measured it is desirable to state it in terms of OC and the power of the lens. The power will be denoted by F and represents the combined power of the distance portion of the correcting lens and the add.

Since the thickness of the correcting lens is always small in comparison to its focal length, it is permissible to use the conventional relation between image and object distances and the power of a "thin lens". Thus,

$$(OC') = \frac{(OC)}{1 - (OC)\ F} \qquad (6)$$

By using this relation and that stated in Equation 5, it is found

$$AG = AC \left\{ \frac{1 - (OC)\ F}{OC} \right\} \left\{ BF - \frac{2\ (AO)\ (ED)}{AE} \right\} \qquad (7)$$

This combined formula takes into consideration the viewing and vertex distances, pupil size, width of seg and power of the correcting lens.

In order to compute the field of fixation with doubling, i.e., with roughly one-half the rays that enter the pupil passing through the segment and the other half passing through the distance portion, the following equation can be employed:

$$AG = AC \left[1 - (OC)\ F \right] \frac{BF}{OC}. \qquad (8)$$

COMPUTED FIELDS OF FIXATION

For clinical purposes, it is desirable to predict the field of fixation through multifocal lenses: this can be accomplished by substituting different values into Equation 7. As an example of the results that can be obtained, the data in Tables 1 and 2 were computed. For these data, a constant viewing distance of 40 cms. was employed. This procedure

is adequate, since the fields of fixation for different viewing distances can be obtained by multiplying the size of the field of view at 40 cms., by a corrective factor. This factor varies with the size of the pupil, the vertex distance and the viewing distance. For purposes of illustration, however, only the factors for a 5.0 mm. pupil are provided (Figure 4).

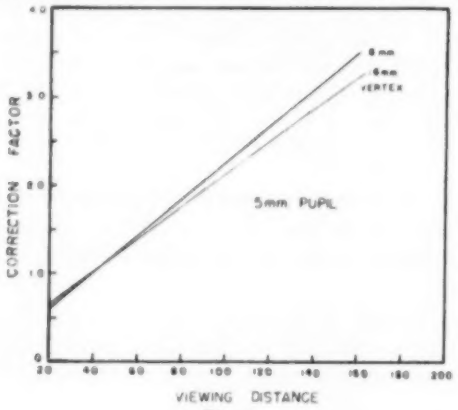

Fig. 4

The data in Tables 1 and 2 are tangential measures in cms., of the field of fixation without doubling. Such fields would be available to a patient if he did not tolerate any monocular diplopia in the use of his multifocal lenses.

TABLE 1

Size of Pupil	Vertex Distance	Size of Segment 6mms. —12	—6	0	+6	+12
2	8	10.47	9.51	8.51	7.51	6.57
	12	9.16	8.20	7.19	6.22	5.24
	16	8.20	7.23	6.25	5.26	4.29
3	8	7.96	7.33	6.47	5.71	4.98
	12	6.98	6.24	5.48	4.74	3.99
	16	6.28	5.53	4.79	4.03	3.28
4	8	5.43	4.93	4.41	3.89	3.40
	12	4.82	4.31	3.78	3.27	2.75
	16	4.37	3.85	3.33	2.81	2.28
5	8	2.92	2.65	2.37	2.10	1.83
	12	2.63	2.36	2.07	1.79	1.51
	16	2.45	2.16	1.87	1.57	1.28

In using the tables, the total power of the lens through the segment region is employed. Also, consideration needs to be given to the range of clear vision in computing the fields of fixation. Only within this range can "clear" vision be obtained.

TABLE 2

Size of Pupil	Vertex Distance	Size of Segment 22mm. —12	—6	0	+6	+12
2	8	51.81	47.06	42.11	37.17	32.50
	12	45.16	40.42	35.46	30.69	25.83
	16	40.28	35.50	30.72	25.86	21.05
3	8	49.30	44.78	40.07	35.37	30.93
	12	42.98	38.47	33.75	29.20	24.58
	16	38.36	33.80	29.25	24.62	20.05
4	8	46.77	42.48	38.01	33.56	29.34
	12	40.82	36.53	32.05	27.74	23.35
	16	36.45	32.12	27.80	23.40	19.05
5	8	44.26	40.20	35.97	31.76	27.77
	12	38.63	34.58	30.34	26.25	22.10
	16	34.53	30.43	26.33	22.16	18.05

For purposes of comparison, the fields of fixation with doubling were computed for the same variation of factors as provided in Tables 1 and 2. The data are provided in Table 3.

For the data in this table, a constant viewing distance of 40 cms. again was used. For other viewing distances, the field is directly proportional.

DISCUSSION

From a study of Tables 1—3, it is apparent that the different factors such as pupil size, power of prescription, vertex distance, etc., markedly affect the field of fixation. In order to gain an appreciation of this effect, two extreme cases can be considered. For the one case, consider the field of fixation for a total power of the correcting lens of —8.00 D. when all the factors are such that a maximum field of fixation is obtained. This value for a 6 mm. segment, an 8 mm. vertex distance, and a viewing distance of 140 cms. is 48.7 cms. for the field of fixation with doubling. For the second case, assume that the total power of the correcting lens is plus 8.00 D., the vertex distance 16 mm., the size of the pupil 5 mm., and the viewing distance 100 cms. With this combination of factors, the field of fixation without doubling is only 2.97 cms. The ratio of these fields is 16.4:1. That is, in the first case with optimal conditions the field of fixation is 16.4 times as large as the field in the second case with maximum restrictions due to the different factors.

The choice of plus and minus 8 diopters is that the included range covers 97 per cent of the prescriptions normally encountered in an optometric practice. The vertex distances employed represent the possible extremes. The same or similar reasons are applicable to the other factors.

The question can now be raised relative to the importance of each

Table 3

Size of Segment	Vertex Distance	—12	—6	0	+6	+12
6mm	8	15.50	14.08	12.60	11.12	9.73
	12	13.50	12.08	10.60	9.17	7.72
	16	12.03	10.60	9.17	7.72	6.29
22mm	8	56.85	51.63	46.20	40.79	35.66
	12	49.50	44.31	38.87	33.64	28.31
	16	44.11	38.87	33.64	28.31	23.06

of the factors affecting the field of fixation. A logical inquiry would be, what is the most important factor? No specific answer can be provided because the relative importance of any one factor depends upon the others. For example, consider the fields of fixation obtained in the three cases listed in Table 4.

TABLE 4

	Cases		
	A	B	C
Rx.	2.00 D.	2.00 D.	2.00 D.
Pupil Size	2mm.	5mm.	no effect
Vertex Distance	12mm.	12mm.	12mm.
Size of Segment	6mm.	6mm.	6mm.
Viewing Distance	100cms.	100cms.	100cms.
Field	without doubling	without doubling	with doubling
Size of Field	16.2cms.	4.67cms.	26.5cms.

In cases A and B the fields of fixation without doubling were computed. These vary in the ratio 3.34:1. The ratio of the fields for

C:A = 1.70:1, and
C:B = 5.68:1.

These ratios show that the relative importance of the tolerance of diplopia depends upon the size of the pupil. With a large pupil the criteria becomes very important and as the pupil becomes smaller, this factor becomes less important.

When the size of the segment is relatively large in comparison to the diameter of the pupil, a variation in the size of the pupil produces a relatively small effect upon the field of fixation without doubling. For the field of fixation with doubling, a change of pupil size produces no effect.

The effect of a variation of vertex distance and power of the prescription clearly is evident from the data. In general, a field of fixation at an 8 mm. vertex distance is 50 per cent greater than at 16 mm.

Also, the field of fixation for a prescription of —12.00 D. is approximately 50 per cent larger than for plus 12.00 D. at a vertex

distance of 8 mm. For a vertex distance of 16 mm., the percentage increase is roughly 100 per cent.

Of particular interest in this investigation, is the effect of the various factors upon the vertical dimension of the field of fixation obtained through intermediate segments. That the size of the pupil produces a marked effect is seen in Cases A and B. For Case B, undoubtedly difficulty would be encountered by the patient due to an inability to locate the small area in the segment where the desired imagery is obtained. In this case, an adequate field probably only would be available from an intermediate segment with a height of 8 mms. or more.

In the preceding discussion, the assumption was made that the monocular fields of fixation were equal in size and thus the same as the binocular field of fixation. When anisometropia is present, the monocular fields differ in size and the binocular field of fixation is only as large as the smaller of the two.

It has been shown that anisometropia over 2.00 D. is encountered in only 3 per cent of the individuals wearing refractive corrections. Consequently, a marked dissimilarity in the size of fields is not frequently encountered.

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REFRACTIVE DIAGNOSIS AIDED BY CONTACT LENS TECHNIQUES*

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During the past 15 years a great deal of time has been devoted to the development of contact lens techniques and to the pursuit of research into the many challenging problems involved in its application. It is my purpose in this paper to suggest that the knowledge gained from the pursuit of new methods and the experience accumulated during the fitting of many thousands of contact lens patients has contributed substantially to the development of optometry as a science. I would further suggest that contact lens technique as a post-graduate study is to be commended alike to the practitioner who wishes to pursue the speciality and to the student who has no such intention.

Each will find in his investigations a widening of his outlook on optometry as a whole, and they will enable him to recognize many interesting eye conditions he might otherwise overlook in his everyday practice. Similarly, experience in the contact lens field inevitably improves one's refractive technique. The practitioner who has engaged in this exacting work acquires certain skills which might never be cultivated in routine refraction. As a result of his special studies, his observation of the anterior portion of the eye will become more detailed and thus considerably more revealing. His inspection of the cornea will be carried out with more than casual interest.

The practitioner who has acquired proficiency in contact lens refraction appreciates the importance of the cornea as the primary refracting surface of the eye. He will be the more likely to recognize departures from normal curvature which not infrequently defy detection by ordinary methods of examination, but which may result in significant changes in refraction. Corneal irregularity may be an active condition, as in keratoconus (the incidence of which would appear to be greater than is generally realized) or a passive one, as in the presence of scar tissue or irregularity left by ulceration or abrasion. Corneal irregularity of sufficient degree to prevent the attainment of a normal standard of visual acuity may all too easily pass unrecognized.

*An abridgment of the material presented before the Contact Lens Section, American Academy of Optometry, Rochester, New York, December 8, 1952. For publication in the April, 1953, issue of the AMERICAN JOURNAL OF OPTOMETRY AND ARCHIVES OF AMERICAN ACADEMY OF OPTOMETRY.

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In all cases of this type—and, indeed, whenever there exists any doubt as to the regularity of corneal curvature, the contact lens provides us with a certain and infallible diagnostic test, for it enables us to superimpose upon the eyeball an artificial cornea of optically perfect curve. Moreover, we have an additional advantage in our precise knowledge of the radius of curvature and the thickness of this superimposed cornea. With its aid we can estimate the degree of visual acuity of which the eye would be capable with an optically normal cornea. So much valuable information may be gained from the application of contact lenses that I would regard them as a necessary accessory to the equipment of the refractionist.

Keratoconus is not always binocular in its incidence. I have seen a number of cases in which an eye has been dismissed as "amblyopic" simply because the acuity could not be improved by lenses, when the real cause of poor vision was corneal malformation of this type.

In one notable instance a young man sought my advice concerning his left eye, the acuity of which had declined to the counting of fingers at half a meter. He had been told that the eye was "lazy" and that nothing could be done to improve it. Yet there was no obvious reason for its deterioration. His fusion was normal. There was no muscular imbalance of any consequence. The cornea and lens were free from opacity, but the fundus could not be sharply focused with the ophthalmoscope. This circumstance, and the nature of the ophthalmometer reading suggested that a corneal malformation existed.

The contact lens test confirmed this diagnosis, for the acuity was improved almost to 6/6 level. The effect of this transformation on binocular vision and steropsis exceeded anything the patient could have imagined. Wearing a contact lens on his left eye, this young man has been enabled to resume certain specialized studies which he had been compelled to abandon.

As an example of the passive type of corneal irregularity another recent case is worthy of inclusion. The patient was a girl of 18, who was wearing a low convex spherical correction. She complained that the lenses made little or no difference to her vision, and although her sight had never been as good as that of other people, she thought it should be possible to obtain at least a little improvement. External examination by focal illumination showed no apparent abnormality of the cornea, which was quite transparent and free from opacity, but the reflected image of the light source indicated irregularity of curvature. Further inspection with the ophthalmoscope revealed a marked degree of irregularity, which led me to inquire whether the patient had suffered

from corneal ulceration as a child. She was unable to recall any such occurrence, but her mother, who was present at the consultation, volunteered the information that the girl had, in fact, almost lost her sight, as a baby, from what she called "very severe inflammation" of the eyes.

The condition of the cornea was quite sufficient evidence of the serious nature of the disturbance at that time, for the best acuity obtainable with a spectacle correction was below 6/24 in either eye. I was readily granted permission to apply the contact lens test, and as I fully anticipated, the effect was remarkable. The vision was raised to rather better than 6/9 in one eye and fully 6/7.5 in the other. The fitting of contact lenses was therefore justified, and the reason for the failure of the spectacle correction became clear.

In these two instances a remarkable improvement in vision resulted from the application of the contact lens test. There are many cases, however, in which no such improvement is possible, and it may appear that the test does not justify the time and trouble involved. On the contrary, I believe that it is a most valuable diagnostic aid, worthy of application as a routine measure whenever there is any doubt as to the basic cause of unsatisfactory vision. It may, by its elimination of the factor of corneal irregularity, indicate the need for further investigation which may well bring to light other helpful information.

The routine outlined in these two examples is valuable in yet another type of investigation which falls within our sphere of service. It is well known that a marked increase in corneal astigmatism is associated with pathology of the cornea, and that a similar, though considerably smaller, increase in the astigmatism of the lens heralds pathological or senile changes of quite a different character. The contact lens, by virtue of its elimination, for all practical purposes, of corneal astigmatism as a factor in refraction, enables us to distinguish between these two conditions with quite a high degree of accuracy.

The value of the contact lens test is not confined to refractive diagnosis, however. It provides a valuable means of examination of the fundus when a sharply focused view with the ophthalmoscope might otherwise be impossible. I recall a case in which a patient, referred by an ophthalmic surgeon for contact lenses, was found to be suffering from an active pathological condition in her left eye. The disease escaped detection until a contact lens had been placed on the eye, when the fundus could be seen clearly. Fortunately, the choroidal inflammation had not reached the macular area, and it was subsequently arrested. When the patient was referred back for the surgeon's attention, he was so interested that he asked me to send her for examination wearing

the contact lens. The occurrence so convinced him of the diagnostic value of contact lenses that he acquired a set purely for this purpose.

The contact lens is no less valuable in facilitating ophthalmoscopy in non-pathological cases. It is well known that in examining the fundus of a high myope, the observer's view is enhanced and the image more readily focused when the patient's spectacles are worn. Surface reflections from the spectacle lenses may prove troublesome, however, especially when the beam of the instrument approachs the macular area. This handicap is almost entirely eliminated when the inspection is made through a contact lens of sufficient concave focal power to correct the refractive error within two or three diopters.

A similar, though less marked, advantage is to be gained in cases of high astigmatic error. In hyperopia and aphakia, however, the contact lens cannot be said to aid ophthalmoscopy to the same degree. The fundus of an aphakic patient is perhaps best seen without any correcting lens before the eye.

In all these investigations into corneal and fundus conditions I employ a simplified type of contact lens made by my colleague, Mr. A. J. Forknall. The lens is 17 mm. in diameter and has a narrow scleral band which rests just beyond the limbus. Although such lenses are not suitable for lengthy periods of wear they are ideal for diagnostic purposes in that they are very easily placed on the eye, even by an inexperienced hand, and they are so comfortable that in practically every case the patient is unaware of the presence of the lens. They are therefore unsurpassed as an introduction to contact lenses—a valuable feature in the kind of investigation I have described, for most of the patients will have had no previous experience in the wearing of a lens and they may be somewhat apprehensive. Moreover, it is frequently noted that a seriously defective eye displays a greater degree of sensitivity than its more normal fellow. This is most probably a type of defense mechanism. Another advantage of this reduced contact lens is that the fitting is by no means critical. A lens of average radius will fit comfortably in practically every case, and even when the radius is incorrect the degree of discomfort experienced is too insignificant to give rise to complaint.

In considering the contribution of the contact lens to diagnostic technique in refraction mention should be made of the peculiar value of the gomioscopic contact lens in the investigation of the angle of the anterior chamber. Although this study is concerned more with ophthalmology than with optometry, it is nevertheless to be regarded as an enhancement of the technique of eye examination arising from

the specialized study of contact lenses. Other types of special lenses are employed in x-ray photography of the eye, as an aid in the location of foreign bodies in the vitreous and lens. High concave lenses are also useful in the investigation of the effect of a telescopic correction.

The application of the principle of the pinhole in visual improvement dates back many years before contact lenses were introduced. Yet the most satisfactory employment of the principle is made possible by a special type of contact lens. A striking illustration of its value arose in my own practice a few years ago, and the case was outlined in a paper the writer presented at the International Optical Congress in London in July, 1952. In brief, contact lenses were designed to provide artificial irides and pupils in a case of aniridia.

Hitherto, the patient had been unable to enjoy satisfactory visual acuity even with deeply tinted lenses, as his effective pupil extended to the corneal margin. Pinhole discs, while they greatly improved his vision, were quite impracticable for general wear and he had resigned himself to a rather miserable existence, finding it necessary to employ four or five pairs of glasses with lenses of varying tints, none of which gave him a reasonable standard of vision. After considerable experimentation a pair of contact lenses were made which provided a pupillary aperture of 2 mm. and these, ground with a suitable refractive correction, enabled him to discard his tinted lenses and enjoy almost normal vision without the distressing intolerance of light he had experienced from childhood. Although such cases are rare, they illustrate one of the most valuable contributions of contact lens technique to the enhancement of refractive correction.

In the study of muscular anomalies, anisometropia and aniseikonia, much may be learned from an application of the contact lens. It cannot, perhaps, be claimed that their use has contributed substantially to our present day techniques, but in certain conditions contact lenses may facilitate the carrying out of recognized orthoptic tests and serve as a helpful diagnostic aid. In high degrees of anisometropia the optometrist will often hesitate to prescribe a full correction for the more defective eye, for the reason that even when a partial correction is worn, the vertical imbalance created by the dioptric disparity between the two lenses it too great to be overcome except when the visual axes coincide with their optical centers. In these circumstances fusion is intermittent and a compensatory suspension of vision may develop. A full correction would intensify this visual habit to the detriment of binocular vision. In many cases, when tests are applied to demonstrate the existence of suspension, with a full correction in the trial frame, the

results are unreliable—indeed, the tests themselves are often confusing to the patient, however intelligent he may be.

While simultaneous binocular vision may be achieved by accurate centration of the trial lenses in relation to the visual axes, there remains the further obstacle to fusion created by disparity in the size of the retinal images. A true estimate of the degree of binocular vision present may be obtained in such cases only when the need for suspension is eliminated. Contact lenses make possible a satisfactory degree of fusion with a much closer approach to equalization of retinal image sizes. It is not suggested that this method should be a routine measure, but it may profitably be applied when a thorough investigation of binocular functioning is called for. Their employment by the practitioner as a part of his refractive technique may guide him in his decision as to what degree of correction will prove most comfortable for his patient and offer the least disturbance to binocular functioning in cases of this kind. In considering contact lenses as an aid to optometry the fact should be recorded that by their aid the visual acuity of the high myope may often be improved appreciably beyond the best obtainable with a spectacle correction.

Not the least of the contributions made by contact lens study to the refinement of regular refractive technique is that it affords the student an excellent opportunity of experiencing at first hand many of the visual problems of his patients. It is known that the practitioner who is himself a wearer of contact lenses will most successfully inspire confidence in the mind of his patient. Similarly, the optometrist who is, for example, myopic, will achieve perhaps his greatest success in prescribing for his myopic patients. His own experience as a wearer of concave lenses not unnaturally endows him with a sympathetic attitude and a keen insight into the problems of the myope. By means of contact lenses (and regardless of his refractive error) the practitioner may become artificially aphakic, highly myopic, hyperopic, astigmatic or anisometropic—indeed, there exists hardly any visual anomaly which he cannot experience personally, if he is so inclined. Furthermore, he can wear lenses which simulate fairly accurately the effect upon vision of certain senile and pathological conditions of the eye. The handicap of lens opacity, for example, may be experienced from its incipient stage to the development of dense opacity for which operation is the only remedy. The effects of corneal nebulae and cataract may be reproduced by painting the opacities on the surface of a contact lens. The handicap imposed upon the patient who suffers from these defects is graphically demonstrated by the wearing of such lenses, and the experience enhances one's understanding of their peculiar problems.

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OCULAR PATHOLOGY IN THE ELDERLY PATIENT

Because of the lengthening life span of citizens generally, optometrists are serving more and more patients over 70. For the greater part, these patients are a real joy to work with as they are appreciative of the help we can give them. Usually their visual problems are of a simple nature and as they have already adapted themselves to whatever ametropias are present they can be given additional help without upsetting current habits or visual patterns. In addition, they are usually not hurried and have the time to fully work out those problems their cases present.

To be sure, these cases are not always simple. At times, the optometrist must call upon all of his technical reserves to diagnose and

properly prescribe for these patients. In addition, there is the obvious possibility of pathology. Here, too, the optometrist must utilize every diagnostic procedure at his command to determine the presence or absence of disease within or affecting the eye or the orbit.

When pathology is found, there is general concensus among optometrists that the case should be placed under the care of an ophthalmologist. There is lack of agreement, however, between optometrists as to just how far the optometrist should go in explaining to the patient the nature of the problem before a consultant ophthalmologist is brought into the case. Nor is there agreement between optometrists as to the amount of clinical data the optometrist should supply to the consulting ophthalmologist.

During his years of clinical practice the writer has attempted to solve these questions in various ways, and from his experience feels that no one method can be recommended to produce the most satisfactory patient reaction in all cases. However, in most cases he has, over the years, come to the conclusion that a frank discussion of the problem with the patient serves the best interest of all concerned. The writer is not suggesting that the optometrist make the final diagnosis. This must properly be left to the ophthalmologist. He is suggesting, however, that where a pathological condition is strongly suggested or evident that consultation be arranged. For instance, in a case of suspected glaucoma, the patient's case history may have aroused some suspicions. The visual acuity is significantly off. Tension by palpation seems to be to the plus side. The anterior chamber seems shallow, yet there has been no pain or congestion and there is no enlargement of the blind spot.

In a case of this nature, the writer suggests that the refraction be completed and that the patient be informed that in the doctor's judgmen a consultation is advisable inasmuch as there is a possibility that the patient may now be in the early stages of glaucoma and if so, both a new correction and medication under careful supervision may be necessary to arrest the progress of the disease. In very doubtful cases the writer explains that he is not at all sure that glaucoma is present, but to completely remove all doubt, prefers to continue with the case only after consultation.

The writer has found that most elderly patients are deeply grateful for the interest shown in their problems and will gladly cooperate with every suggestion. They are naturally apprehensive, but if they are given the assurance that everything that can be done will be done,

the apprehension wears off quickly and a new interest in overcoming or checking the problem takes its place.

This cannot come to pass, however, until a full understanding is reached between the patient and the optometrist on the nature of the suspected glaucoma (or other pathology) and the part the patient, the optometrist, and the ophthalmologist must play in preserving useful vision for the patient. This understanding can come only through a careful discussion of the nature of the problem and the need for cooperation on the part of the patient. Most elderly patients are eager to cooperate and their understanding and help is of great assistance. This is true not only in cases of suspected or actual glaucoma but other ocular pathology as well.

After the consultation has been decided upon, all diagnostic data and refractive findings are presented to the consulting ophthalmologist for his consideration, along with a request for a clinical report on the patient's condition after he has studied the case.

In general, ophthalmologists are most cooperative in handling these elderly patients with pathological conditions referred to them for consultation by optometrists. They realize as do we all, that in the patient's best interests, this cooperation must exist.

In addition, by taking the patient into his confidence and fully explaining the problem or possible problem to the patient, the optometrist is merely treating the patient as a mature adult and is enabling the patient to adjust his plans for the future to the realities of the present. This can and should be done in a reassuring manner to the end that everything that can be accomplished in the patient's interest will be done and that his welfare is uppermost in the minds of all. The writer has found that this type of service to the elderly patient brings its own great reward in the lasting appreciation of these patients.

CAREL C. KOCH

TRANSACTIONS OF THE AMERICAN ACADEMY OF OPTOMETRY

A department devoted to announcements, reports, appointments, organization data, news, professional problems and ideals, as these relate to the Academy.

ACADEMY PLANS LUNCHEON AT A. O. A. CONGRESS

A luncheon for Academy members is being planned for the coming Congress of the American Optometric Association in June at the Seneca Hotel, Rochester, New York. Chairman of the luncheon planning committee for the Academy will be Dr. Morton Abram, President, Chicago

College of Optometry. Tuesday, June 23 is the date. 12:30 P. M. is the time. All Academy members are urged to attend the A.O.A. Congress and meet with their guests at this special Academy luncheon. Academy President, Dr. Meredith W. Morgan, Jr., School of Optometry, University of California, will preside at the luncheon and Dr. James F. Wahl, President of the A.O.A. will welcome the Academy to this annual meeting of the Association.

FEINBERG REPRESENTS ACADEMY AT A.O.A. SEMINAR

On March 22, 1953, Dr. Richard Feinberg, President, Northern Illinois College of Optometry was guest speaker at the American Optometric Association's annual occupational vision seminar in Columbus, Ohio at the School of Optometry, The Ohio State University. Dr. Feinberg spoke on "The Contribution of the American Academy of Optometry to the Occupational Vision Field."

LOCAL CHAPTER ACTIVITIES

ILLINOIS

A breakfast meeting of the Illinois Chapter of the Academy was held during the Illinois Optometric Convention, and the following officers and committees were elected:

President, Dr. T. Fenwick Taylor, Ottawa: vice president, Dr. Richard Feinberg, Chicago: secretary-treasurer, Dr. Grace Stevesson, Chicago: corresponding secretary, Dr. T. Murroughs, Chicago. Executive Council: Dr. N. K. Wesley, Dr. F. Kushner, and Dr. O. Engelmann, all of Chicago. Program Committee Chairman: Dr. Eugene Freeman, Chicago. Nominating: Dr. Don Frantz, DeKalb; Dr. W. Brown, Elgin; Dr. H. McCormack, Zion. Educational: Dr. Richard Feinberg, Dr. G. N. Jessen, Chicago: Admittance and Examining: Dr. Harry Pine, Dr. T. R. Murroughs, Dr. O. Engelmann, Chicago.

SOUTHERN CALIFORNIA

Friday the Thirteenth was the dinner date for the March meeting of the Southern California chapter which heard Dr. Harry Jankiewicz, (Ph.D.) talk on the "Inheritance and Characteristics of the Blue Sclerotics Syndrome." This paper was also read at the Rochester meeting of the Academy in December, 1952.

NEW YORK

Newly elected officers for 1953 in the New York Academy of Optometry are: President, Dr. Joseph Carlson: vice president, Dr. Samuel Frank: treasurer, Dr. Willis B. Blee: secretary, Dr. Herman Sager.

New York Fellows heard a lecture and demonstration on the "Practical Aspects and Application of Corrected Curve Lenses" by Dr. Edward Bechtold, Columbia University School of Optometry, at the February, 1953 meeting.

CURRENT COMMENTS

Virginia Huck
Editorial Assistant

Optometrists will confer a favor by sending news items of general interest for this department: such as relate to new instruments, clinical techniques, education, visual health and optometric legislation and organization.

FIRST JOINT FAR EAST MILITARY OPTOMETRIC SEMINAR

News from the Far East—Dr. Warren H. Low, Lieutenant in the United States Navy, writes the following interesting item for the Journal:

The first Joint Far East Military Optometric Seminar was successfully held at the Itazuke Air Force Base, Fukuoka, Kyushu, Southern Japan on February 23-25, 1953, with optometric officers from all the branches of the armed forces represented on opening day. Chairman 2nd Lt. Irving Dunsky welcomed this professional gathering, who had traveled from Tokyo or Yokohama in the northern island of Honshu to Sasebo, on the southern tip of Kyushu.

The purpose of this combined service get together was to exchange ideas and problems confronting individual eye doctors in terms of finding a common solution to the military optometrist, the Services, and professional optometry.

The conference was attended by Lt. Warren H. Low, U. S. Navy, from the Eye Clinic, Sasebo; 1st Lt. Lewis H. Fox, 8162nd Army Unit, Fukuoka; 2nd Lt. Irving Dunsky, Itazuke Air Force Base; 2nd Lt. Edward Seefelt, Johnson Air Force Base, 8th Hospital Group, Toyooka; 2nd Lt. Seymour Saltzman, 610th Air Force Hospital, Nagoya; 2nd Lt. Warren Broderson, 7th Hospital, Far East Air Mat. Command, Tachikawa; 2nd Lt. Melvin Grossman, Army Hospital, Yokohama, and Staff Sergeant Norman Woods, 141st General Hospital, Hakato, Japan.

The following six major definite problems were considered most paramount in relation to service-connected visual care, and were thoroughly discussed at the conference:

The acquisition of special type of lenses such as flat top bifocals, absorptive filters, telescopic lenses, coated lenses, post operative cataract

lenses and contact lenses in situations where a need is shown.

Limiting of refractive examinations, visual analysis, and prescription writing to commissioned optometrists.

The possibilities of establishing a separate Optometric Corps with representatives in Washington.

Establishing a definite equipment allowance list for eye testing and training procedures, which would be standardized for the services.

Initiating schools and careers for optometric assistants within the services.

Setting up orthoptic clinics in various strategical, geographically located areas, manned by optometric officers, and subject to referral.

All of the above were reduced to writing and will be submitted as Resolutions in a Joint Ophthalmological-Optometric Conference in Tokyo, in June, 1953.

On the second day of the seminar, each optometrist presented his entire procedure of examining a patient in the service, discussing the time spent, visual tests performed, and methods of analyzing data. By this method each officer was given an insight into techniques or methods that, prior to the conference, might have been completely foreign to his particular branch. Questions were directed to speakers in a brisk 10 minute discussion period following each dissertation.

Three speakers were chosen from the group to represent Optometry in the proposed Joint Ophthalmological-Optometric conference. Dr. Norman Woods will speak on "Malingering Tests in the Army," Dr. Irving Dunsky chose as his topic, "A very reliable test for Amblyopia in the Air Force," and Dr. Warren H. Low will speak on "The Application of Special Lenses to Naval Optometric Problems."

During the closing ceremonies held after luncheon at the Air Force Officers Club, Itazuke Air Base, the group resolved to continue their organized efforts to maintain a united, well organized group in military optometry in order to uphold the standards of the service in general, and professional optometry in particular.

PENN STATE GOES TO SIX YEARS

At a recent Board of Trustees meeting in Philadelphia the Pennsylvania State College of Optometry Board of Trustees voted to increase the length of the Optometry Course at that College from five years to six years of undergraduate study. This will become effective with the enrollment of the September, 1955 optometry (3rd year men) class. The new courses in optometry at the Pennsylvania State College of Optometry will consist of two years of pre-optometric work and four

years of specialized optometric studies. Penn State becomes the first optometric school or college to go on a six-year basis. Other institutions will probably take similar steps in the near future.

MERGER TALKS SUSPENDED

For the past two months exploratory meetings have been held in Chicago to determine the feasibility of a merger between the Northern Illinois College of Optometry and the Chicago College of Optometry. These talks started at the time the Chicago College Board of Trustees announced the removal of the College from its present north side location to the campus of the Illinois Institute of Technology. Preliminary conferences indicated that most of the factors affecting a merger could be readily resolved, but the negotiations were finally suspended with regret because of the N.I.C.O. lawsuits between former and present Board of Trustees members now pending in the courts in which Northern Illinois College of Optometry appears to be one of the defendants. There is a possibility that the talks will be resumed in the future when these legal problems are resolved.

ANNUAL CONGRESS A.O.A. AT ROCHESTER

The annual meeting of the American Optometric Association will be held in Rochester, New York, at the Seneca Hotel, June 21-24, 1953. The A.O.A. will hold its regular three-day business session and will honor the Bausch and Lomb Optical Company who are this year celebrating their founding just 100 years ago. A number of alumni reunions will be held during the Congress and there will also be a special annual meeting of Beta Sigma Kappa during the four-day period. Optometrists in attendance will be taken through the several optical manufacturing plants in Rochester and the vicinity during the convention period. A short educational program is planned. All Academy members are urged to attend the 56th annual Congress of the A.O.A.

NATIONAL BOARD OUTLINES 1953 EXAMINATIONS

The National Board examinations will be given in three Parts. These Parts are defined and outlined as follows:

Part I. Non-clinical and non-professional subjects to include such subject matter as is taught in the optometry schools and colleges prior to the final year and which is not necessarily taught with emphasis on clinical and professional application to the practice of optometry.

Part II. Clinical and professional subjects, to include such subject matter as is taught in the optometry schools and colleges with principal emphasis on clinical and professional application to the practice of

optometry and to participation in related professional activities, plus such subject matter as could otherwise be included in Part I except for the fact that it is taught in the final year.

Part III. Practical examination in clinical and professional skills.

Parts I and II are further divided into subsections to facilitate scheduling. The subsections are identified broadly by their principal subject matter, as follows:

Part I			
Section	I.	Visual Science I	3 hours
Section	II.	Theoretical Optics	3 "
Section	III.	Anatomy	2 "
Part II			
Section	I.	Visual Science II	3 "
Section	II.	Theory and Methods of Optometry	3 "
Section	III.	Ophthalmic Optics	2 "
Section	IV.	Diseases of the Eye	2 "
Section	V.	Social, Legal, Economic and Professional Aspects of Optometry	1 "
Part III			
Section	I.	Clinical and Professional Skills	2 "

The examination date for Part I is June 29, 1953. This part may be taken by applicants who have graduated since January 1, 1952, and by students who have completed all but their final year in optometry. The examination dates for Part II are June 30 and July 1. The examination for Part III will be conducted by individual Clinical Examiners appointed by the National Board. Clinical Examiners will be available in all 48 states. The examination time and place for Part III will be individually arranged through the Secretary. Parts II and III may be taken only by students who have completed their professional courses.

Requests for applications should be sent to John R. Uglum, O.D., Secretary, Mitchell, South Dakota.

THE EDGAR D. TILLYER MEDAL

Walter A. Stewart, president, American Optical Company, presented to the Optical Society of America dies for the Edgar D. Tillyer Medal, which the Company has created for biennial award by the society for outstanding scientific contributions in the field of vision.

Presentation was made at a banquet at the annual meeting of the society, March 21, New York City, at which Dr. Tillyer was a guest. Dr. Brian O'Brien, society president, gave the acceptance speech.

The medal is a tribute to the achievements of Dr. Tillyer during his 37-year career in research for American Optical Company. Outstanding among his many developments in the field of vision are the Tillyer lenses, a complete series of spectacle lenses correcting both spherical and cylindrical marginal errors.

The first Edgar D. Tillyer Medal will be awarded by the society in 1954.

NEWS BRIEFS

The Council on Education and Professional Guidance of the American Optometric Association has provisionally accredited the new College of Optometry at the University of Houston, Houston, Texas, according to a recent announcement. Twenty-five students are enrolled in the school's first class. . . . Omega Epsilon Phi, optometric fraternity on the campus of Pacific University, contributed $50.00 to the College of Optometry's Physiology of Vision Laboratory for research. The money will help defray research cost of experiments in which the electrophysiological effects of light flashes on the human eye will be studied. The fraternity sets aside 40 per cent of its funds for research donations. . . . Albert B. Wells, chairman of the board of American Optical Company from 1925 to 1946, died March 10, 1953, at the age of 80. . . . The 1953 edition of publications available through the National Society for the Prevention of Blindness was released in March. Available bulletins include articles on children's eyes, eye diseases, illumination, industrial vision and safety, nursing service, and vision testing charts. Also availabale are films, radio material and posters. For further information write the Society at 1790 Broadway, New York 19, New York, ask for Publication 32. . . . New Ulm, Minnesota chose as its outstanding young man of the year, Elmo Hill, manager of the N. P. Benson Optical Company in New Ulm. The honor was made in recognition of Hill's work in many civic groups in 1952. . . . Sylvester K. Guth, in charge of lighting research, Lamp Division, General Electric Company addressed the student body of the Northern Illinois College of Optometry on "Light and Seeing" at a special student meeting, March 9. . . . Univis Lens Company announces a complete line of green multifocal lens blanks for summer use. These lenses may be prescribed in either the medium or dark shade of green absorptive lens shades. . . . Pennsylvania State College of Optometry announces the appointment of Dr. Robert Spreat as College Registrar. . . . Continental Optical Company's new Browcrest frame for men is made in mocha, a new attractive color for men's wear. . . . April 20 is the date of the Southeastern Regional Conference on Visual Problems of School Children sponsored by the Alabama Optometric Association and the Department of Psychology of the Alabama Polytechnic Institute. The conference, which is held for teachers and optometrists will be at the Institute, at Auburn, Alabama. . . . According to the Edison Electric Institute, next year will be the Diamond Jubilee of first practical incandescent lamp. . . . Senior students at the Northern Illinois College of Optometry now visit the Illinois Eye and Ear Infirmary in groups of five, twice each week to view cases of ocular pathology and eye surgery.

BOOK REVIEWS

THE SCIENCE OF COLOR. Committee on Colorimetry of the Optical Society of America. New York: Thomas Y. Crowell Company, 1953. 385 pp. $7.00.

The student of physiological optics, if he enquires into the bases of color vision, soon finds himself inextricably enmeshed in contradictory theories and unrelatable facts. Colorimetry, the study of the measurement of color, has assumed the status of a scientific discipline of considerable value to industry. Yet its procedures and terminology are often poorly described and this adds to the confusion permeating the whole subject of color.

Practically since its inception the Optical Society of America has striven to clarify this field. Under the chairmanship of Dr. Lloyd A. Jones a committee on colorimetry consisting of physicists and psychologists has been laboring for twenty years. Its report has now been published in book form.

Nearly half of the book is a readily understood discussion of the physical, physiological and psychological aspects of color and the remainder contains technical details concerning the physical and psychophysical methods of measuring and specifying color. The whole report is characterized by a definitive, authoritative and scholarly exposition of the subject and this, together with the eminence of the personnel responsible for it, will probably make it the standard work in this field for a long time.

The book is to be highly recommended to all students of physiological optics and to those who in the course of their professional work are called upon to deal with some of the physical or psychological aspects of color. Technically it is well produced and the 25 full-color plates, 102 diagrams, 40 numerical tables, and over 500 references make it enjoyable reading as well as a wealth of information.

G. WESTHEIMER

OPHTHALMIC PATHOLOGY, AN ATLAS AND TEXTBOOK. By Jonas S. Friedenwald, Helenor Campbell Wilder, A. Edward Maumenee, T. E. Sanders, John E. L. Keyes, Michael J. Hogan, W. C. and Ella U. Owens; with the editorial assistance of Helen Knight Steward; Publisher under the joint sponsorship of the American Academy of Ophthalmology and Otolaryngology and the Armed

Forces Institute of Pathology; W. B. Saunders Company, Philadelphia, Pennsylvania. 1952. Price $18.00. 489 pages, with CCLX Plates.

This book is an outgrowth of the Atlas of Ophthalmic Pathology by DeCoursey and Ash, which was based upon material in the Registry of Ophthalmic Pathology and which had considerable success as an educational medium. The Registry of Ophthalmic Pathology is the oldest component of the American Registry of Pathology. Ophthalmologists have contributed specimens and records over a period of thirty years. Hence, an outstanding collection of valuable material has been accumulated and its coordination, analysis and interpretation carried on by members of the staff of the Armed Forces Institute of Pathology has made it available for greater usefulness in study.

The new version presents, as did its predecessor, a clear and complete coverage of the morphologic pathology of the eye. In addition, the new feature is the inclusion of the discussion of physiologic mechanisms that influence pathologic changes. The many excellent illustrations, are brought up-to-date in the present book.

The text is written by eminent investigators in the field of ophthalmology and represents the most advanced and authoritative thought on ocular pathology. It provides a solid foundation for the interpretation of clinical manifestations of ocular disease.

ROBERT E. BANNON

ANNOUNCEMENTS

THE AUSTRALIAN COLLEGE OF OPTOMETRY

The new Handbook of the Course of Optometric Science of the Australian College of Optometry has just been received. The Handbook reviews the four-year course in optometry given jointly by the University of Melbourne and the Australian College of Optometry. Students enroll in the university for their non-optometric work and take their optometric science and clinical subjects at the College of Optometry. The Australian College of Optometry is located at 177 Collins St., Melbourne, C. 1., Australia.

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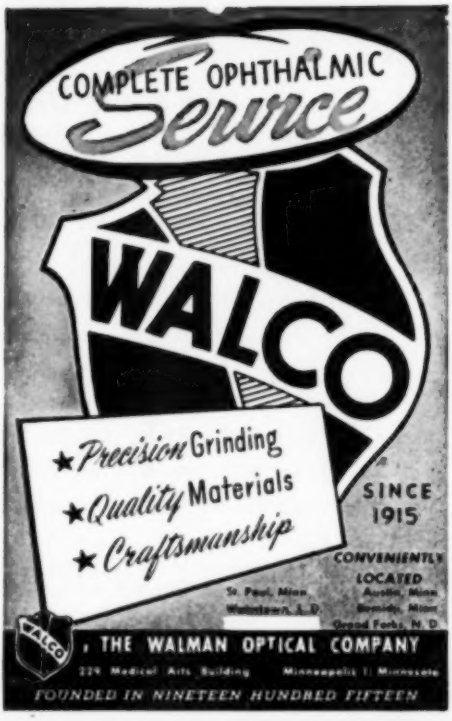

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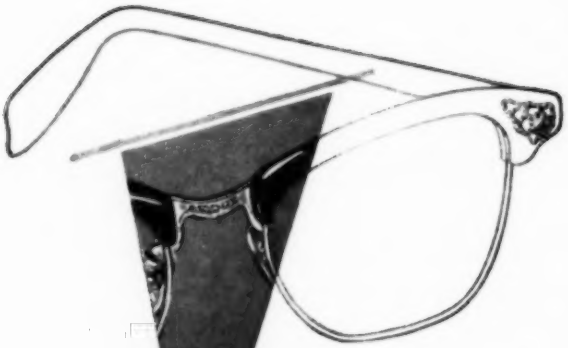

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